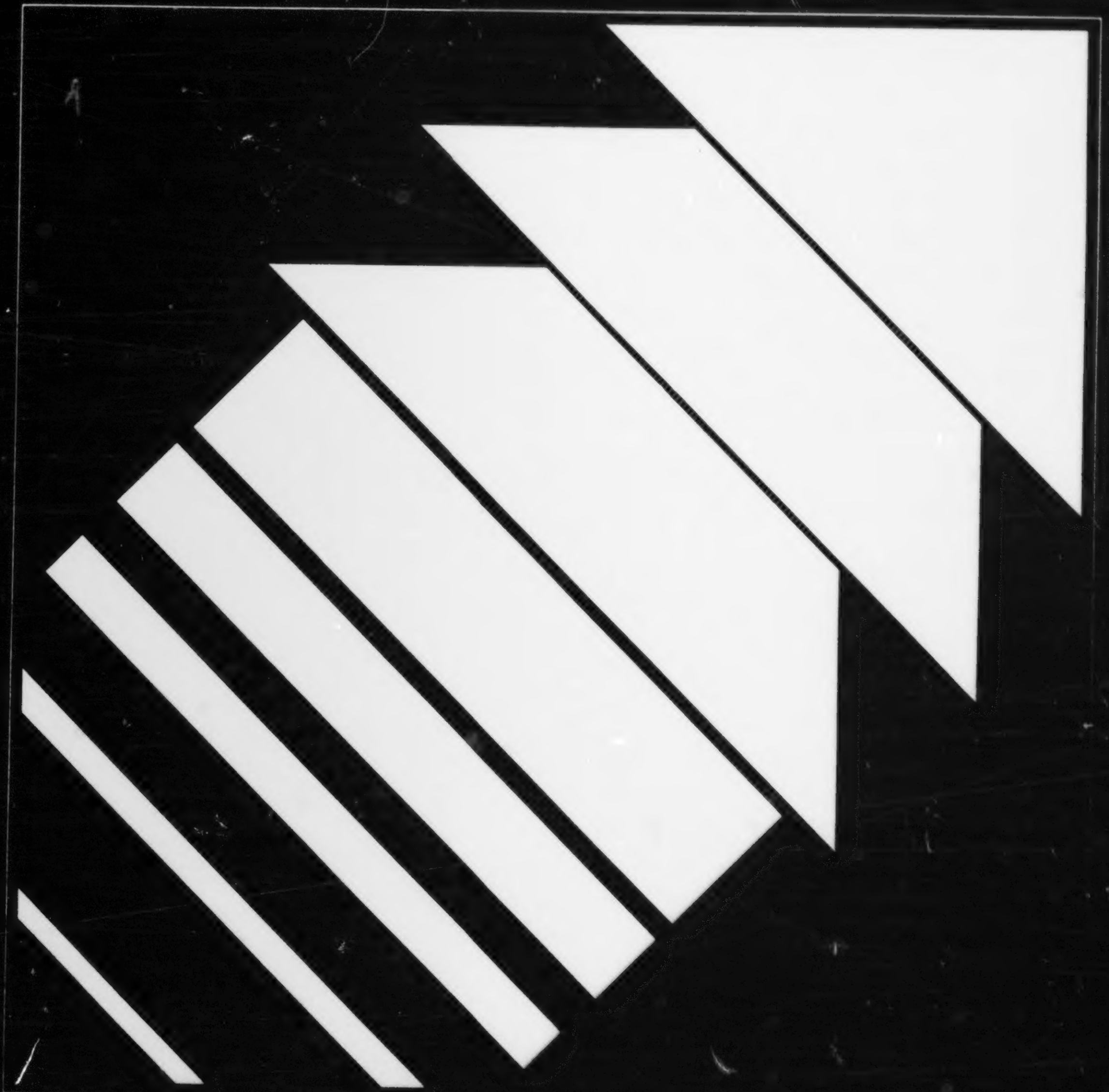
NATIONAL
URANIUM
TAILINGS
PROGRAM



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GUNNAR FIELD STUDY
CONTRACT NO. 15SQ.2341-4-1674X
VOLUME 1
SUMMARY REPORT

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BBT PROJECT NO. S84-1750

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MICROMEDIA

EXECUTIVE SUMMARY

In the early 1950's, a uranium discovery on the Crackingstone Peninsula of Lake Athabasca led to the development of the Gunnar uranium mine and mill complex, along with an associated townsite and support facilities. Ore was produced from an open pit and underground mine until the mid 1960's, when ore reserves began to decline and the market for uranium softened. The waste treatment practices which were in use at the time would be considered inadequate by today's standards. Waste rock was piled adjacent to the open pit on a natural surface of bedrock and silty glacial lake clays. The tailings, resulting from a sulphuric acid leach and magnesium diuranate precipitation process, were discharged without neutralization or treatment to Mudford Lake, located less than 1 km to the northwest of the mill site. The tailings flowed from a wood stave pipeline and spigot into the lake until the basin filled to capacity. Additional capacity was gained by blasting the outlet of Mudford Lake and allowing the tailings slurry to flow down into a small basin now called Gunnar Central and beyond this into Langley Bay, off Lake Athabasca. Following site abandonment, no special decommissioning activities were undertaken. During the late 1970's and early 1980's, a series of site investigations supported by a provincial and federal agencies were undertaken. These studies addressed environmental aspects of the tailings and waste rock areas.

In 1982, the National Uranium Tailings Program, funded by the Federal Government was formed and given a 5-year mandate with which to investigate the long-term significance of various methods of management of uranium mine tailings in Canada. One part of this program was to carry out a series of laboratory and field investigations that would collect data on fundamental environmental processes to determine the rate at which the processes occur at field sites.

Two field sites were chosen for detailed investigation. One site was a pyrite-rich, acid-producing tailings known as the 'Lacnor Site' located near Elliot Lake, Ontario. The second was a neutral tailings site called 'Gunnar'. In October of 1984, a contract was awarded to BBT Geotechnical Consultants Ltd. of Saskatoon, Saskatchewan to investigate the Gunnar site. Field activities began in late November of 1984, following a period of program design and mobilization. Field investigations were carried out during the winter of 1984-85 and into August of 1985, at which time equipment was removed from the site. The objective of the field program was to collect integrated environmental data on the meteorology, tailings solids, tailings groundwater, surface water runoff and biology of the tailings area. As well, several special studies investigated the waste rock area, the presence of discontinuous permafrost in the tailings, and quality control and quality assurance associated with the data collected. These data were compiled, with very little interpretation, into a series of data appendices. A summary report was also produced which provides an overview of the program and the data collected.

Meteorology

The meteorological data, collected principally by means of an automatic weather station erected near the center of the Main Gunnar Tailings area, included wind speed and direction, solar insolation, temperature, precipitation and relative humidity. These data were collected to allow interpretation of:

1. how permafrost may have developed in the tailings,
2. dust blowing off the tailings, and
3. a water budget for the tailings including precipitation, evapotranspiration, and groundwater and surface water runoff.

The data confirmed that the site, despite being adjacent to a large lake, was in a semi-arid environment that is frozen for approximately 7 months of the year. Total annual precipitation is about 350 mm per year. Temperatures in June and July ranged as high as 35°C and as low as -42°C in January and February.

Tailings Solids

The tailings solids were sampled by drilling boreholes on all of the 3 major tailings areas. These borings penetrated through sandy, silty tailings which overlaid thick deposits of silty clays. The tailings solids contained residual rock minerals and varying amounts of chemical process precipitates. The principal precipitate material was calcium sulphate through most of the tailings, although in some areas, magnesium sulphate was relatively common. Very little pyrite was found and the tailings have an excess neutralization capacity, although oxidation/reduction reactions with iron and other salts have resulted in the tailings being acid (pH 4) in some areas. The majority of the tailings solids contained between 1 and 10 percent sulphates as calcium and magnesium salts. Uranium values were generally near 50 ug/g or 0.6 Bq/g as U-238. The concentrations of the U-238 decay products (Th-230, Ra-226, Pb-210) in the solids generally ranged from 5 to 10 Bq/g, consistent with the grade of ore reported being processed.Geotechnically, the tailings are stable, with some wind erosion and dune formation occurring on parts of the main tailings area. Gamma radiation readings over the year at 1 m above the surface ranged from 100 to 600 uR/h, with winter values being about one-half of those measured in the summer.

Tailings Porewater

The water table is located within a metre or two of the surface of most of the tailings areas, although along one side of the main tailings area, it is at a depth in excess of 5 m. Because the tailings areas are underlain by both a very impervious granitic bedrock and impervious silty clays, there is very little, if any, groundwater seepage from the tailings area. The tailings porewater chemistry and tritium dating of the porewater suggests that the near surface porewaters of the tailings are being flushed out on a seasonal basis during spring runoff and summer rain events. The deeper tailings porewater appears to move only very slowly into the near surface environment. The presence of a series of seasonal recharge and discharge areas, coupled with the semi-arid environment in the area, has resulted in the seasonal formation of crusty white salt (calcium and magnesium sulphate) deposits on some areas of the tailings. Tailings porewater is dominated chemically by calcium, magnesium, iron and sodium, with pH values ranging from near neutral to slightly acidic. Th-232 and daughters were at very low levels (near their detection limit), while Th-230 values were generally lower than 1 Bq/L. Radium-226 values were generally less than 5 Bq/L, with some values as high as 7 Bq/L. Lead-230 and polonium-210 values were lower. Uranium levels in the porewater of deep tailings ranged from 2 to 8 mg/L (25 to 100 Bq/L U-238), reflecting a much higher solubility of uranium than its decay products.

Surface Waters

Surface water runoff flows from Gunnar Main to Gunnar Central and then to Langley Bay. Surface water runoff also moves from Cutoff Langley to Langley Bay on a long-term basis. Langley Bay water exchanges with Lake Athabasca. In excess of 90 percent of the surface water flow from the tailings area was found to occur in early May to June, within the first few weeks of spring runoff. During this time, there is still considerable frost in the tailings, and flushing of tailings porewater is limited and highly diluted. Low surface water flow rates from June through the end of the monitoring in August increased only in response to rain events. Rain events over the tailings area resulted in a rise in the water table and a hydraulic discharge of waters to the small streams draining the tailings. A beaver dam near the outlet of the main tailings area across the main discharge channel served to dampen flow peaks.

The water discharged during summer rain events has a chemical composition very similar to the shallow groundwater in the tailings, which is partly diluted after a rainfall event. The chemistry of the runoff water shows considerable seasonal variation, with major chemical parameters such as sulphate, calcium, magnesium and sodium dominating at a near neutral pH. The activity of Ra-226 and Th-230 generally ranges between 0.5 to 1 Bq/L, while uranium ranged from 0.2 to 0.4 mg/L or 5 to 10 Bq/L, reflecting the same proportionately higher uranium solubility as observed in the tailings porewater. Flow proportional water sample data, from a flow recording and sampling weir located between the Main and Central Tailings area, will allow an overall chemical mass balance to be made. Evaluation of chemical data in the stream draining the tailings areas, Langley Bay and Lake Athabasca, along with bathymetric data, shows that a high level of water exchange occurs between Lake Athabasca and Langley Bay.

Biology

The amount and type of vegetation growing on the tailings is controlled by both the physical and chemical nature of the surface soil. Areas of the main tailings area where the water table is deeper are characterized by shifting and unstable sands. Vegetation is sparse, being limited to a few willows, wild rose bushes and horsetail. In the lower areas where the water is ponded, a cattail marsh community is present. In some of the areas where the water table fluctuates within a meter or so of the surface, sparse salt-tolerant grass communities are found. Where surface salt levels are relatively high, such as on 'Gunnar Central', vegetation is very sparse. In areas that have been relatively well flushed with a water table close to the surface, such as the 'Frog Pond' just below Gunnar Main, there is very dense grass and tree growth on the tailings material.

Slightly elevated levels of some radionuclides could be found in vegetation on the tailings when compared to vegetation growing on soils off the tailings. Radionuclide levels in vegetation were lower than in the tailings solids upon which they were growing. Environment Canada collected and analyzed a large number of fish from the Langley Bay area in 1983, just prior to the start of this study. After Environment Canada has had a chance to review these data, they will be made public and will complement the data presented in this report. There was no evidence that, at the present time, there is any significant harvesting or consumption of local vegetation, wild game or fish that may contain significant levels of radionuclides originating from the Gunnar Tailings or Waste Rock areas.

Special Studies

On the Main Gunnar Tailings area, elevated mounds of tailings which were blown free of snow in the winter were found to have zones of permafrost. The development of the permafrost lenses, which were delineated by drilling and monitored seasonally by the thermistor probes, appeared to be related to a combination of proximity of the mounds to the water table, fine silty tailings material, and lack of snow cover to insulate them in the winter. An EM (electromagnetic) survey was carried out in an attempt to outline perennially frozen tailings. The results of the EM survey were inconclusive, however, due to the high conductivity of the tailings.

Studies were carried out on the Waste Rock Pile located adjacent to the flooded open pit. The waste rock was calcuated to occupy a volume of 2.7×10^6 m^3. Surface radiation levels were observed to be on the order of 150 uR/h, with some spot readings as high as 1 mR/h. A small seepage stream exiting the western side of the waste rock pile, sampled for water quality, showed a pH just above neutral, with higher than background levels of calcium and magnesium sulphates. Radium-226 concentrations were at or near 1 Bq/L and uranium levels were at or near 2 mg/L. A series of groundwater samples collected from shallow piezometers installed into the silty clay surrounding the waste rock pile, showed similar uranium values but somewhat lower levels of calcium, magnesium and sulphate. Groundwater seepage rates are estimated to be a small percentage of overall water losses from the Waste Rock Pile area. Dust samples collected from Waste Rock areas were analyzed for radionuclide levels, and the presence of secular equilibrium with uranium suggests that the dust has originated from waste rock material and not blown over from the tailings area.

Quality Control and Quality Assurance

The chemical and physical data collected as part of this program were subjected to an extensive quality control and quality assurance program. Many samples were collected in duplicate, and a series of blind replicates and interlaboratory cross-checks carried out. The range of concentrations of elements analyzed often varied over 5 orders of magnitude within the same sample, and special attention had to be paid to interferences and matrix effects. A series of internal data cross-checks, such as electroneutrality balances, was run consistently on water samples and, if these showed data variability of greater than 5 percent, analyses were repeated and the data rechecked. The quality control analyses also showed the presence of solubility constraints on a variety of minerals, such as calcium sulphate found in the tailings. The presence of sulphate complexes in some of the samples dictated that special care be taken to ensure that dilution of samples in the laboratory, which permitted measurement within a calibrated instrument range, was reflecting true initial concentrations and not solubilization of colloidal or molecular complexes.

Data Presentation

The data collected as part of this study has been presented in 2 parts. A summary report provides an overview of all of the data collected, while the appendices present all of the detailed data collected as part of the various study components. The data were collected and presented in such a way that they can be used to develop descriptions of mechanisms responsible for controlling the rate of radionuclide and stable element release from the tailings. If a long term tailings model is developed, these data can also be used in its calibration. This report does not provided any in-depth interpretation of the data, nor does it comment on the overall environmental significance of radionuclide and trace element releases that were measured to occur from the Gunnar tailings.

THE GUNNAR FIELD STUDY

The Gunnar Field Study consists of 10 volumes, each published separately. Volumes 2 to 10 are supplements to Volume 1, written as Appendices 1 to 9.

The 10 volumes are:

- Volume 1 - Summary Report
- Volume 2 - Test Procedures and QA/QC Program (Appendix 1)
- Volume 3 - Atmospheric Studies (Appendix 2)
- Volume 4 - Tailings Solids and Surrounding Soils (Appendix 3)
- Volume 5 - Groundwater (Appendix 4)
- Volume 6 - Surface Water (Appendix 5)
- Volume 7 - Biology (Appendix 6)
- Volume 8 - Waste Rock (Appendix 7)
- Volume 9 - Eating Habits of Local Population (Appendix 8)
- Volume 10 - Permafrost (Appendix 9)

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1.0 INTRODUCTION

This report presents the results of a study relating to characteristics of tailings material, groundwater, surface water, biologic and atmospheric environs of an abandoned uranium mining site. The study site was the Gunnar Minesite in Northern Saskatchewan. The study was performed during 1984 and 1985.

Principal requirements of the study were to design and implement a sampling plan to measure appropriate physical and chemical properties of various materials presently existing within the minesite environment. Collection of samples and related analyses were continued throughout a period of approximately 9 months. Terms of reference for the study required collection and assembly of data. Interpretation of results, modelling and related analyses were excluded from the requirements of the study. The project objectives were summarized in the Request for Proposal as follows:

> " The design and operation of a sampling program, incorporating chemical, physical and biological data, that will be used to characterize the Gunnar tailings and environs, and which will provide raw data for the study of processes involving tailings constituents and their pathways. "

The overall report consists of 10 volumes. This volume presents a summary of the project with the other 9 volumes serving as appendices to it, and presenting detailed results of the various technical components.

1.1 SCOPE OF THE STUDY

1.1.1 Terms of Reference

Terms of Reference for the Gunnar Field Study were set out in the Request for Proposal and various amendments to the Contract, which was entered into between the Crown and BBT Geotechnical Consultants Ltd. The principal requirements of the study were directed to designing a sampling plan and measuring various chemical and/or physical characteristics of tailings solids; soil below tailings; adjacent soils and rock; surface water; tailings porewater; atmospheric components; and waste rock. In addition, data relating to various biological factors were to be collected, and a topographic survey of the study site was required.

1.1.2 Participants and Organization

The Gunnar Field Study was performed by a consortium of firms providing technical expertise in the various fields involved in the work. BBT Geotechnical Consultants Ltd. was the project sponsor providing overall project management and coordination. The principal team firms and areas of involvement were as follows:

Firm	**Project Responsibilities**
BBT Geotechnical Consultants Ltd. Saskatoon, Saskatchewan	Project Management Site Logistics Tailings Solids Tailings Porewater (Assist) Waste Rock Topographic Survey Permafrost
IEC BEAK Consultants Ltd. Mississauga, Ontario	Technical Coordination Surface Water Biology Human Exposure

Sergent, Hauskins & Beckwith Geotechnical Engineers Inc. Albuquerque, New Mexico	Tailings Porewater
Concord Scientific Corporation Downsview, Ontario	Atmospheric Waste Rock (Assist)

In addition, a number of firms were retained to provide specific services:

Prairie Mapping Ltd. Regina, Saskatchewan	Topographic Mapping
Saskatchewan Research Council Saskatoon, Saskatchewan	Chemical and Radionuclide Analyses, Petrology
BEAK Analytical Laboratories Mississauga, Ontario	Chemical Analyses
Associated Helicopters Ltd. Edmonton, Alberta	Helicopter Service
McNeill Northern Services Ltd. Saskatoon, Saskatchewan	Drilling and Soil Sampling
Monenco Analytical Laboratories Ltd. Calgary, Alberta	Chemical and Radionuclide Analyses
P. Pehme Waterloo, Ontario	Electromagnetic Survey

Project organization was established to provide coordinators responsible for principal tasks, in addition to staff responsible for management functions. Figure No. 1.1 shows the Project Organization.

PROJECT ORGANIZATION CHART

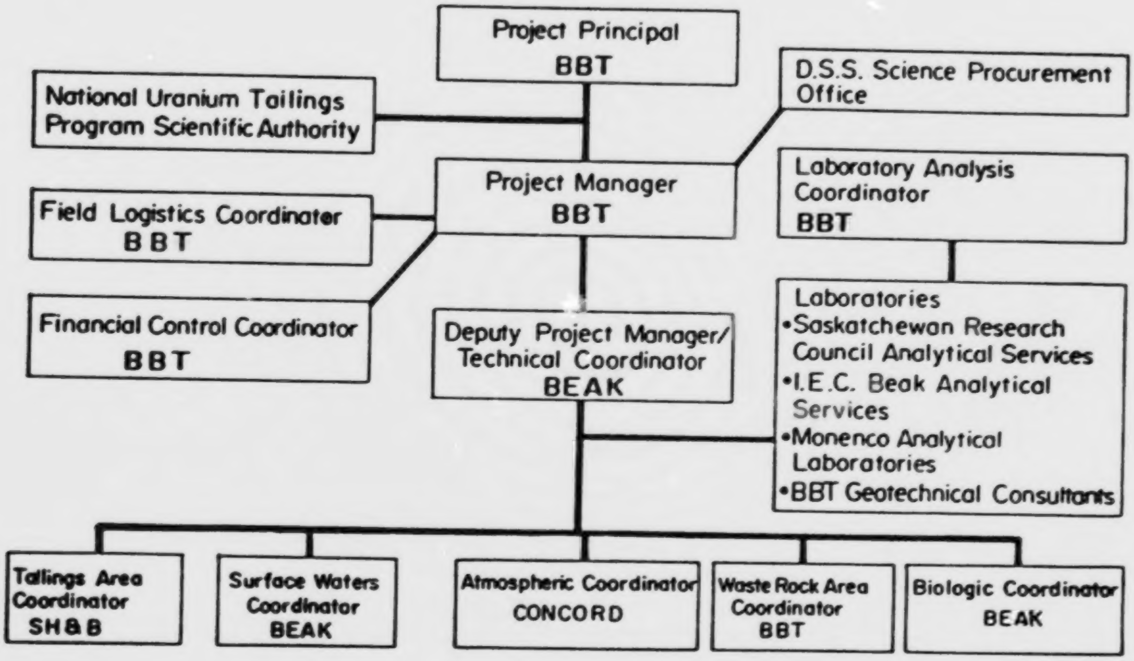

Project Principal
BBT
National Uranium Tailings Program Scientific Authority
D.S.S. Science Procurement Office
Project Manager
BBT
Field Logistics Coordinator
BBT
Laboratory Analysis Coordinator
BBT
Financial Control Coordinator
BBT
Deputy Project Manager/ Technical Coordinator
BEAK
Laboratories
•Saskatchewan Research Council Analytical Services
•I.E.C. Beak Analytical Services
•Monenco Analytical Laboratories
•BBT Geotechnical Consultants
Tailings Area Coordinator
SH&B
Surface Waters Coordinator
BEAK
Atmospheric Coordinator
CONCORD
Waste Rock Area Coordinator
BBT
Biologic Coordinator
BEAK

FIGURE NO. 1.1

1.1.3 Schedule and Duration

The work described in this report was ongoing during the period October 1984 through March 1986. Fieldwork was performed intermittently during the period from late October 1984 to August 1985. Planning, analytical work, data compilation and report preparation were undertaken both prior to and after fieldwork. Schedule and durations of principal activities relating to the study are shown in Table 1.1.

TABLE 1.1

GUNNAR FIELD STUDY
SCHEDULE OF ACTIVITIES

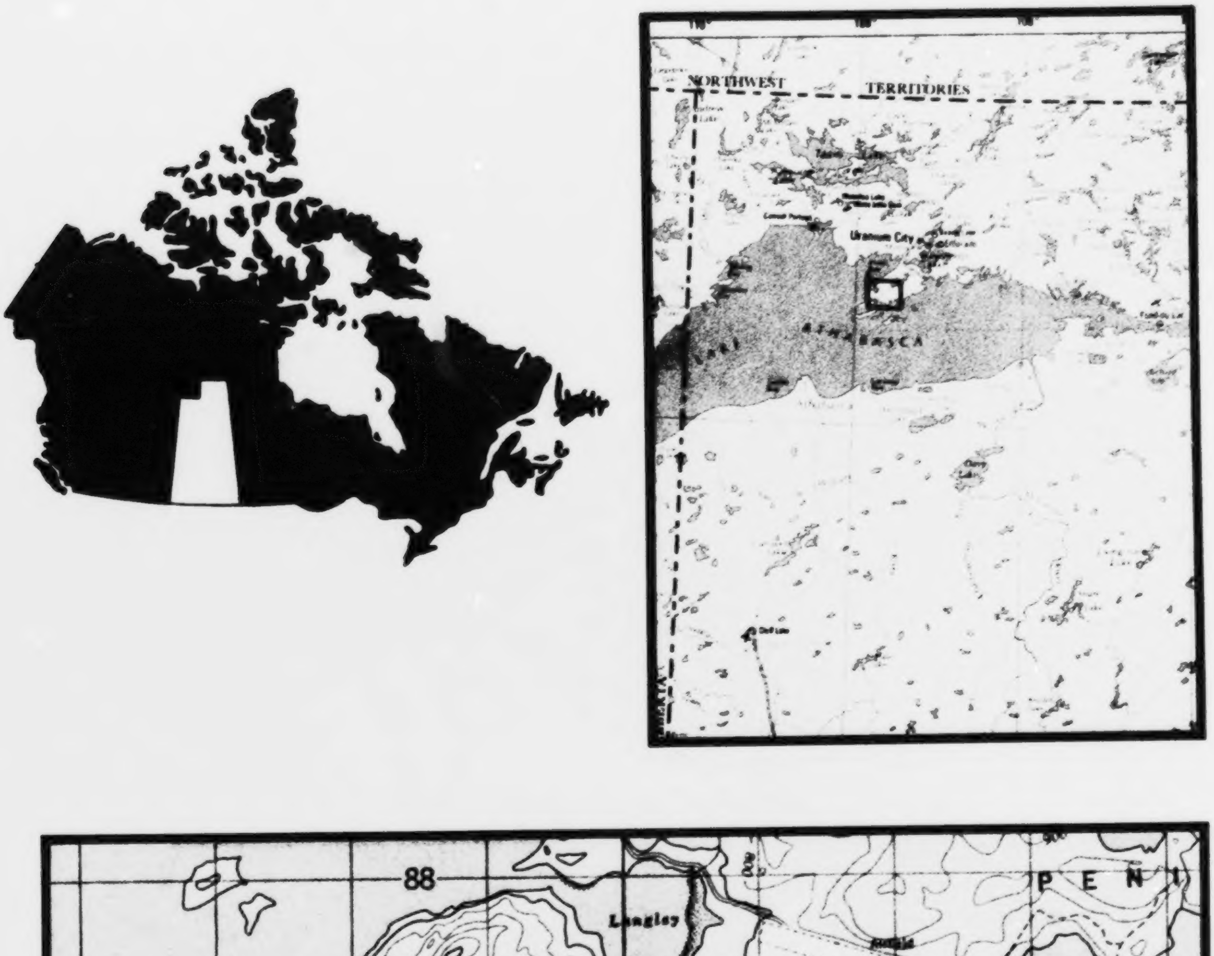
	Activity	Start	Finish
1.	Proposal Call	June 26, 1984	August 20,1984
2.	Notification of Contract Award	October 18, 1984	
3.	Initial Project Meeting With Scientific Authority	October 22, 1984	
4.	Initial Meeting of Technical Coordinators	October 25, 1984	October 26, 1984
5.	Topographic and Control Surveys	October 25, 1984	March 19, 1985
6.	Preliminary Sampling Plan Design	October 29, 1984	November 16, 1984
7.	Mobilization/Demobilization Equipment and Materials To/From Uranium City and Gunnar	October 23, 1984	November 5, 1985
8.	Meeting with Scientific Authority to Review Initial Sampling Plan Design	November 16, 1984	
9.	First Field Installation/ Sampling Campaign	November 25, 1984	December 12, 1985

Activity	Start	Finish
10. Chemical/Radionuclide Analyses of Samples	December 16, 1984	November 15, 1985
11. Final Sampling Plan Design	November 17, 1984	April 15, 1985
12. Collection of Meterological Data	December, 1984	September, 1985
13. Second Field Installation/ Sampling Campaign	March 4, 1985	March 31, 1985
14. Field Sampling	April 29, 1985	May 5, 1985
15. Field Sampling	June 18, 1985	June 25, 1985
16. Field Sampling	July 25, 1985	July 30, 1985
17. Field Sampling	August 22, 1985	August 29, 1985
18. Compilation of Data	December 15, 1984	November 30, 1985
19. Draft Report to Scientific Authority	January 6, 1986	February 28, 1986
20. Draft Report Comments From Scientific Authority	January 13, 1986	March 15, 1986
21. Final Report	March 31, 1986	

1.2 DESCRIPTION OF THE STUDY AREA

1.2.1 Study Location

The study site was the Gunnar Minesite located at approximately 59° 23' North latitude and 108° 53' West longitude, situated approximately 25 km southwest of the community of Uranium City, Saskatchewan, Canada. Location of the study site is shown on Figure No. 1.2.


NORTHWEST TERRITORIES
Uranium City
LAKE ATHABASCA
88
87
85
84
83
16
17
19
20
23
24
Langley Bay
Adair Lake
Radio Station
Spring Lake
Gunnar
Open Pit
Wharf
Ascot Islands
Marys
Hilyard Island
Island
PENI
750
800
850
900
950

Location of Study Site

FIGURE 1- 2

The minesite was constructed on the Crackingstone Peninsula, near the north shore of Lake Athabasca. The surrounding terrain is rugged Precambrian Shield typified by numerous areas of bedrock outcroppings. Photograph No. 1.1 is a photograph of the project site from an airplane and shows the abandoned minesite, the open pit, the waste rock piles and the main tailings area (Mudford Lake).

An overview of the geology of the area and the Gunnar site in particular is presented in Volume 4 - Appendix 3, "Tailings Solids and Surrounding Soils".

1.2.2 History of Operation

Details of the mining operations at the Gunnar mine have been discussed in a number of publications, including a comprehensive article published in the Canadian Mining Journal in 1962, entitled "The Gunnar Story".

The mine/mill operation was carried on during the period 1955 to 1964. The site operation was self-contained, with housing and all essential services being provided at or adjacent to the mine/mill site. Logistical support for the operations at this remote northern site included transportation by barge from Waterways, Alberta during the shipping season, and aircraft service from Edmonton, Alberta year-round. There was no road access established to the site.

The mining operation was conducted initially from an open pit, with a shaft and headframe subsequently constructed to enable exploitation of the deposit below depths practical from the open pit. The average ore grade was approximately 0.175 percent magnesium diurinate as finely disseminated pitchblende and uranophane in a syenite containing approximately 8 percent calcite and 2 percent to 3 percent hematite. A total of slightly more than 5 million tonnes of ore was processed on site in a sulphuric acid-sodium chlorate ion-exchange plant. The ore was ground to greater than 50 percent finer than 0.074 mm. The precipitate was concentrated as magnesium diurinate with the refining process reportedly estimated to be 92.5 percent efficient.

The mill tailings were mostly deposited by slurrying into a small lake originally known as Mudford Lake, and referred to as Gunnar Main Tailings, lying to the southwest of the mill. As the capacity of Gunnar Main became depleted, a small rock ledge at the lake outlet was blasted out to permit the tailings slurry to flow downstream to a small depression referred to as Gunnar Central Tailings, and then into Langley Bay in Lake Athabasca, creating further deposition referred to as Langley Bay Tailings. In September 1960, a mine backfill plant commenced operation. Published information indicates that approximately 40 percent of the mill tailings was placed in the mine after that date.

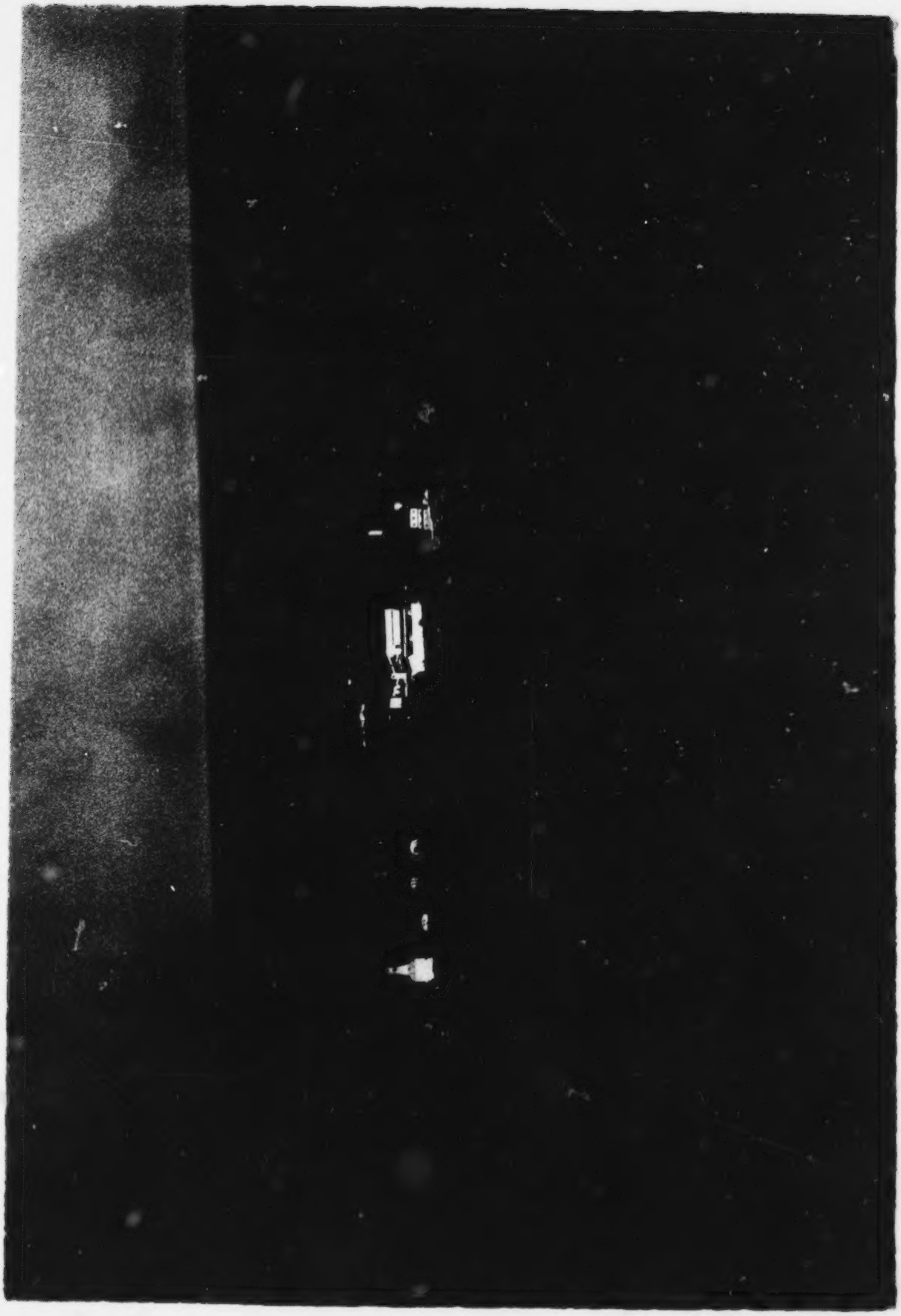
The total tailings discharge to tailings ponds was estimated to be 4.4 million tonnes. The tailings discharge was approximately 30 percent solids and contained the ion exchange barren plus sewage effluent collected from several septic tanks located strategically in the townsite and camp areas. The tailings slurry was discharged without neutralization.

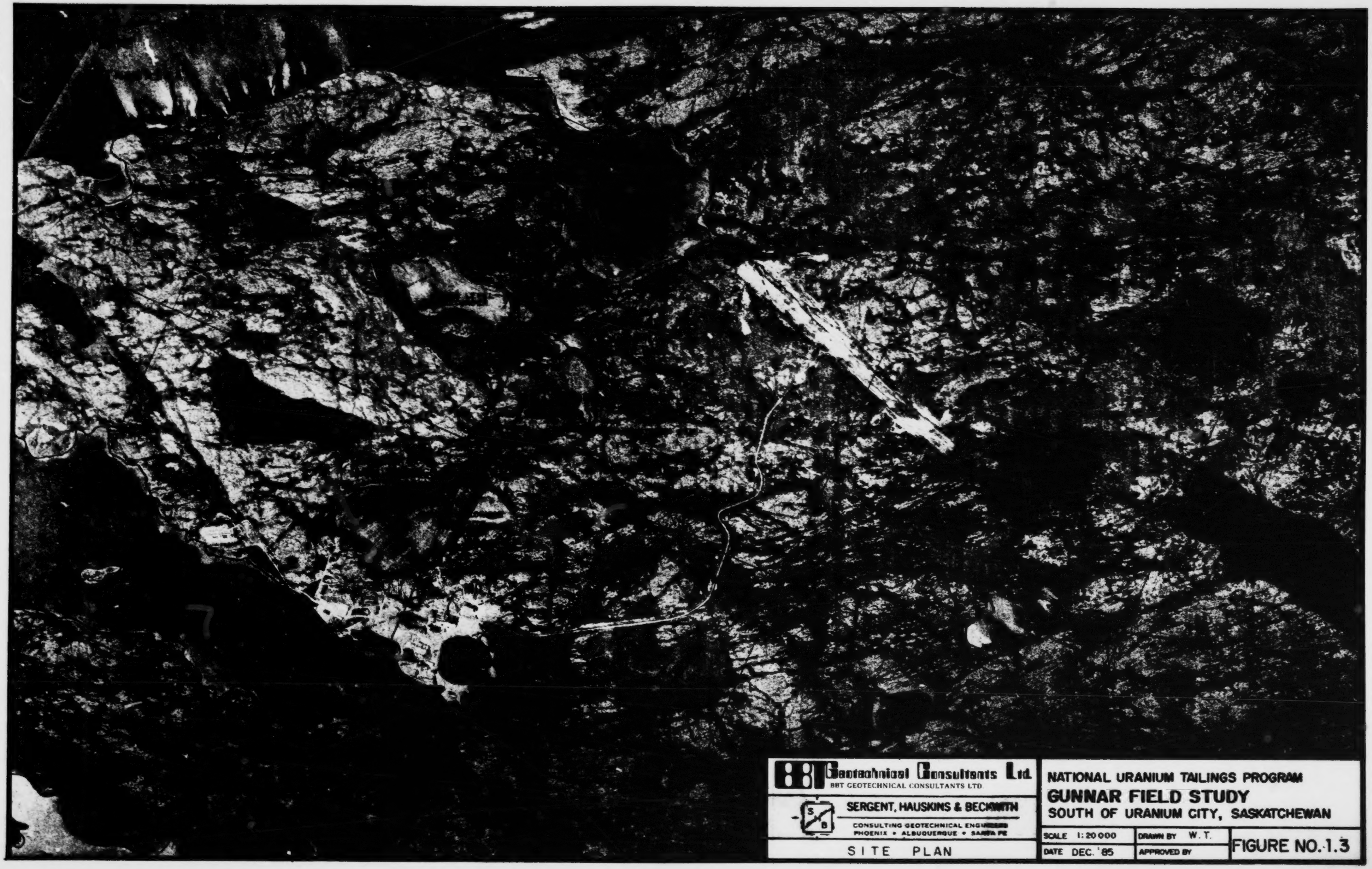
Stripping and waste rock from the open pit operation were stored in 2 intersecting piles located to the southeast of the open pit. These piles constitute one of the dominant features of the landscape at the abandoned minesite. The majority of the waste from the shaft and headframe operation was stored underground.

The layout of the mine development and relationship of various features is shown on Figure No. 1.3.

PHOTOGRAPH NO. 1.1

The Gunnar Minesite - August 1984





BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD.

SERGENT, HAUSKINS & BECKWITH
CONSULTING GEOTECHNICAL ENGINEERS
PHOENIX • ALBUQUERQUE • SANTA FE

SITE PLAN

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1:20 000	DRAWN BY W.T.	FIGURE NO. 1.3
DATE DEC. '85	APPROVED BY	

1.2.3 Site Description

Figure Nos. 1.4 and 1.5 show the site in stereo air photo presentation and illustrate tailings deposition areas in "before and after" condition. Figure No. 1.4 is from air photo coverage taken in 1955 when site development was in the initial stages. Figure No. 1.5 is from site coverage in 1976 after mining operations had been discontinued for approximately 12 years, and is generally representative of conditions existing at the time of this study.

The area surrounding the Gunnar minesite is mainly bedrock with a thin layer of overburden supporting a growth of short to medium sized coniferous trees. The bedrock lows are filled in with some clay-silt lacustrine deposits or glacial fluvial deposits and in some cases, with peat bogs. The mine and mill site had been stripped and generally remained unvegetated at present. The waste rock pile supported some very sparse plants. The buildings that remained are in disrepair. The tailings areas were generally unvegetated with evidence of windblown sand and silt at the surfaces.

1.2.4 Topographic Survey

As part of the work, detailed topographic mapping of the study area was produced. Timing of the fieldwork did not facilitate placing control targets and running up-to-date air photo coverage due to the presence of snow cover. The mapping was therefore produced by applying current ground survey control to 1:25,000 air photo coverage from 1976. The following site benchmarks were established:

TBM 0 - Top of turnbuckle on a large steel roller drum by the airstrip, assumed elevation 100 m.

TBM 14 - Northeast corner of main shaft building top of steel rail on top of concrete foundation, elevation 75.461 m.

Topographic mapping was produced at a scale of 1:5000 and enlarged to 1:2000. Figure Nos. 4.6 and 4.7, included in Volume 4 (Appendix 3), show site topography at 1:2000, together with pertinent features of the study area.

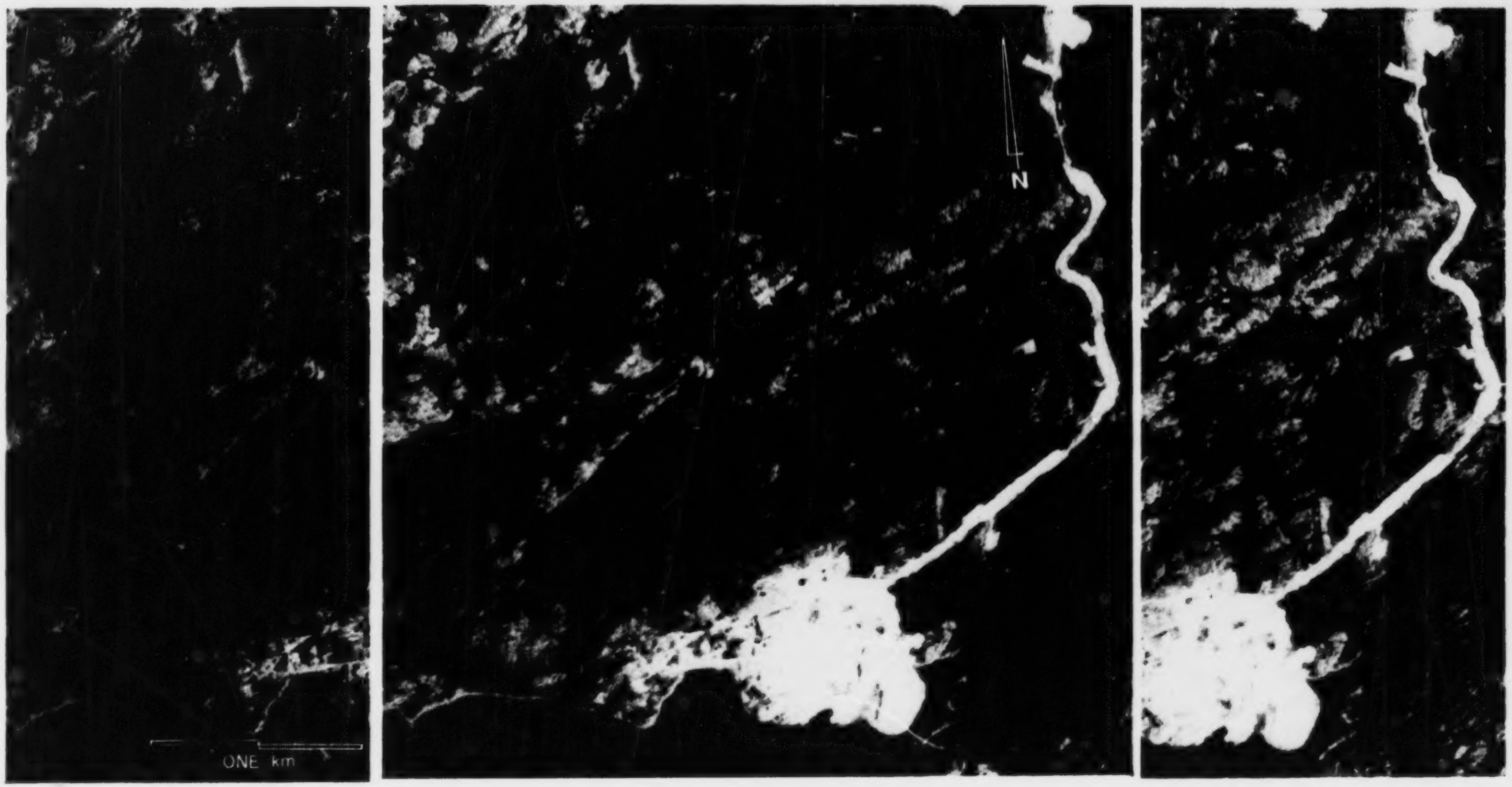


FIGURE 1.4 GUNNAR MINESITE - STEREO TRIPLICATE
JUNE 1955

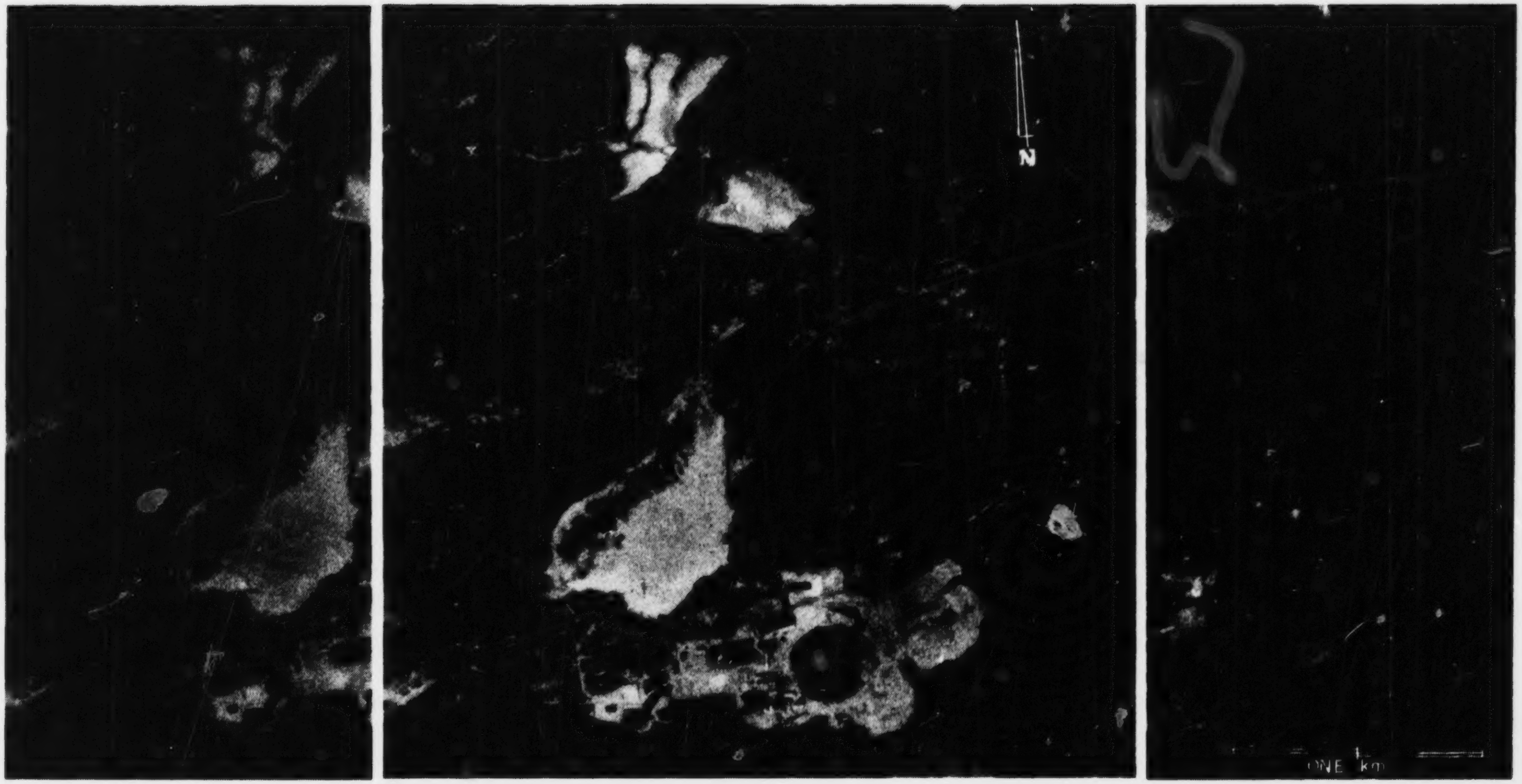


FIGURE 1.5 GUNNAR MINESITE - STEREO TRIPLICATE
MAY 1976

1.3 PREVIOUS STUDIES AND REPORTS

In the vicinity of the Gunnar uranium mine and mill tailings site, several previous studies have been undertaken that relate principally to the levels of radionuclides, trace elements and nutrients found in surface waters, fish, surficial tailings, and vegetation. In addition, several taxonomic surveys of vegetation and aquatic biota have been undertaken and species inventories compiled. Harms and Fraser (1982) describe plant communities on the tailings, giving frequency, abundance and percent cover for plant species in each community. Redmann and Frankling (1982) give a plant species inventory and associated tailings chemistry. Kalin (1981) provides data on trace metal content of tailings vegetation and associated tailings. Tailings vegetation studies have concentrated on Gunnar Main, while also providing limited data for Gunnar Central and Langley Bay. Data on uranium and thorium isotopes in vegetation and vegetation biomass are lacking from previous reports, as are data of any kind from the Frog Pond between Gunnar Main and Gunnar Central. There are limited data available for the Waste Rock Pile. These data may be important for validation of food chain transport and mass balance models.

Previous studies of aquatic biota in the Gunnar area include an Environment Protection Service (EPS 1981) study in Langley Bay and Lake Athabasca, and Tone's (1982) Saskatchewan Research Council (SRC) study of the Gunnar Flooded Pit and Lake Athabasca. The EPS report provides data on fish catch, fish radionuclide content (Ra-226, Pb-210, Th-230), associated water and sediment chemistry, plankton and benthic insect densities, and plankton biomass. Tone's report provides data on fish catch, fish radionuclide content (Ra-226, Pb-210), associated water and sediment chemistry, and densities of benthic invertebrates, plankton and sediment bacteria. In addition, some seepage water quality data from the Waste Rock Pile are presented. Comparable bacterial data for the tailings are lacking from past reports.

A second EPS study of aquatic biota in the Gunnar area was completed in July 1983, but results have not been made available as of February 1986. These results will include data on radionuclide (Pb-210, Po-210, Ra-226, Th-228) and trace element content in water, sediment, aquatic macrophytes and fish.

A recent Canadian Forestry Service (CFS) study of Gunnar tailings vegetation was completed in 1983. Vegetation samples were provided by CFS for radionuclide and trace element analysis as part of the present study, along with unpublished CFS data on uranium content of vegetation samples.

No detailed hydrogeological or surface water hydrology studies have been undertaken prior to this study, although a few spot flow measurements have been made as part of the biological and water chemistry studies. All of these studies have been referenced in this document, and the relevancy of the information they contain related to the data collected for this investigation is discussed.

1.4 GENERAL STUDY PLAN

The administrative constraints associated with this project dictated that it start in the early winter of 1984 and finish all field data collection in the early autumn of 1985. The technical objectives called for an interdisciplinary study that would allow both a qualitative and quantitative understanding of how the natural environmental processes responsible for the mobilization and transport of tailings materials into the open environment occur. In meeting these objectives, it was necessary to undertake a complete review of previous work that had been carried out on the site, and then select key study areas for detailed investigation at times of the year where the maximum amount of information return could be gleaned for the effort expanded.

1.4.1 Integration of Study Plan Components

The mobilization of trace elements and radionuclides in the Gunnar tailings and waste rock areas is dependent upon a variety of physical, chemical and biological processes that are very closely interrelated. Data collection procedures were initiated in order to ensure that data collected in one particular discipline would tie together with data from other disciplines. This was done in order to ensure that the total system could be understood.

Meteorological data on wind speed and wind direction were collected to be able to model atmospheric transport of wind-blown dust and radon gas. The complimentary data collected in the tailings solids study, to allow this to be done, was surface grain size and moisture content data. Field calibration data, to verify model data on a local scale for the winter months, involved the collection of dust trapped in winter snow and its analysis for grain size distribution, morphology, and radionuclide and trace element levels. Rainfall and snow pac data were collected to use in conjunction with the surface runoff data, and relative humidity and temperature data, to construct an overall water balance for the Gunnar Main tailings area. The fact that vegetation is relatively sparse on Gunnar Main, and the tailings area is underlain by thick silty clays making groundwater losses insignificant, allows 2 independent checks on the water balance to be carried out. Radon gas, and surface and off-pile gamma radiation fields were measured as primary data.

The groundwater and tailings solids programs were designed to provide both a basic mass inventory of the tailings and soluble constituents of possible concern, and data on the proportion of readily water soluble material versus the total inventory. The water soluble inventory is the portion of the total inventory that may be of environmental concern within the next few thousand years. Data on tailings solids collection and analysis were coordinated with the groundwater collection and analysis so that tailings porewater equilibrium data could be obtained in addition to data on leaching kinetics. The data on tailings permeability and water level elevations were collected in order that groundwater discharges from the tailings to surface ponded water and runoff could be calculated.

Surface water flows were monitored continuously during the open water season in order to assist in determining a water balance on the tailings. This water balance, as one of its primary pieces of information, supplies surface runoff response to precipitation events. The water chemistry of this runoff water is measured in order to allow a calculation of how much of the total inventory of water soluble constituents in the tailings, including trace elements and radionuclides, is being exported to Lake Athabasca on a seasonal and yearly basis.

Biological data collected in this study consisted both of characterization of bacterial populations in the tailings area, and of characterization of the plant communities growing on and around the tailings and waste rock areas. Whereas bacterial communities were only characterized as to the species present in the tailings, the surface plant communities were also analyzed for their radionuclide and trace element composition. At several sites, surface soil or tailings were also analyzed in order that bioconcentration factors could be calculated.

The original study design allowed for the netting of a variety of fish species in the receiving environment of Langley Bay, and the analysis of their gut contents and tissues for trace element and radionuclide analyses. Environment Canada, however, had just carried out this same study the preceding year (1984). It was decided to make use of the Environment Canada data rather than repeat the study. Unfortunately, the Environment Canada data are still under review and not available for release as an attachment to this study.

The overall design of the study has thus been carried out to ensure that all of the data from the interrelated study components can be tied together and the effect of the tailings on the overall environment over the long-term be calculated.

1.4.2 Integration With Other Study Data

As discussed in Section 1.3, a series of previous studies focusing primarily on the surface water chemistry of Langley Bay, and the flooded pit and vegetation communities on the tailings have been carried out. In designing this particular field investigation, it was necessary to review these studies and to ensure that the data collected could be related to that collected in previous studies. This involved, where practical, the sampling of the same type of site, the use of similar analytical methods, and the involvement of individuals who had worked on these previous studies and at the mine while it was in operation.

1.4.3 Location of Study Sites

It was necessary, in a study of this nature where slightly less than one full year of field data could be collected, to focus study effort on sites which would provide a high rate of data return for the effort invested. The location of the various data collection points was thus arranged to try to meet this objective.

Of particular interest from the viewpoint of developing an atmospheric release model for radon and dust, and for calculating a water balance for Gunnar Main, was the location of the meteorological station. The station was located, prior to the study, in a small grove of trees on the southeastern side of the tailings. To meet the objectives of this study, it was moved to a central location on Gunnar Main as shown on Figure No. 1.3.

A preliminary reconnaissance of the study area suggested that the highest percentage of the surface flow from the Gunnar Main tailings discharges through a bedrock gorge between Gunnar Main and Gunnar Central. A stream weir outfitted with an automatic flow recorder and a flow proportional sampler, both powered by solar charged storage batteries, were installed in this bedrock gorge at the location shown in Figure No. 1.3. The small amounts of seepage flow that are occurring out of the south and eastern part of the tailings basin are of a very diffuse nature and not monitorable by a surface weir. Similarly, the flows from Gunnar Central to Langley Bay occur via 2 possible routes around a bedrock high with diffuse seepage flow through old beaver dams. Because of logistical considerations, no flow recorder or automatic sampler was placed at this location. A seepage area on the southwestern side of the waste rock area was not instrumented for similar reasons.

The principal focus of the study at the Gunnar site was to collect basic information on the tailings to understand what types of geochemical and transport processes had been operational over the last 21 years since abandonment. The majority of the studies was focused on Gunnar Main for a variety of reasons, the major ones being: 1) the range of geochemical environments available; 2) the depth of the tailings and the range of permeabilities across the tailings; 3) the presence of discontinuous permafrost; and, 4) the presence of a range of vegetative communities. Supplementary data were collected from the Langley Bay tailings, the Gunnar Central tailings and the revegetated tailings to the east of the berm on Gunnar, as well as the waste rock area.

The specific rationale for the selection of particular study sites is discussed in the appropriate appendices.

1.4.4 Timing and Logistics of Field Programs

The timing of various fieldwork programs was in large measure dictated by seasonal and transportation considerations. The contract commenced in late October 1984, at which time the Gunnar site was already under snow, and barging operations on Lake Athabasca had been discontinued for the season. This was one of the earliest winters on record. It became necessary to revise the sequence and methods for a number of the plans which had been formulated in the proposal stage. The most significant revisions involved change of project transportation mode to helicopter with snowmobile assistance, use of a light helicopter-transportable drilling unit, and the housing of personnel in Uranium City.

Aside from the topographic survey, which was discussed under Section 1.1.3, fieldwork for the purpose of installing various instruments and monitors was performed during 2 major campaigns, one during the period November 25, 1984 to December 12, 1984, and a second during the period March 4 to 31, 1985. Logistical support for these campaigns involved the following:

- Local air carrier (Norcanair) for transportation of personnel and small goods from Saskatoon to Uranium City.

- Charter aircraft for transportation of heavy goods and freight from Saskatoon to Uranium City.

- Helicopter for transport of goods, freight and personnel between Uranium City and the Gunnar study site, and between locations at the study site.
- Snowmobiles for transportation at the study site.
- Lodging and meals for project staff at commercial accommodation in Uranium City.
- Rented truck for local transportation in the Uranium City area.

Following the initial 2 field campaigns, there were a number of site visits, generally with representatives from 2 or more of the technical disciplines to attend to instruments, collect samples or data monitors, and do some minor installation work. Details of these visits and logistical support were as follows:

Dates	**Disciplines**	**Logistical Support**
April 29, 1985 to May 5, 1985	Surface Water Atmospheric	Helicopter Accommodation in Uranium City
June 18 to 25, 1985	Groundwater Surface Water Atmospheric	Float Plane Boat Tent Camp at Gunnar
July 25 to 30, 1985	Atmospheric Biology	Float Plane Boat Tent Camp at Gunnar
August 22 to 29, 1985	Surface Water Groundwater	Float Plane Boat Tent Camp at Gunnar

There were also a number of one-day site visits performed by local personnel employed to assist with the study. The purpose of these visits was to inspect or service equipment, measure water levels, and collect samples. Transportation was by snowmobile, float plane and boat as appropriate to seasonal conditions and undertakings.

Site communication during field campaigns was by portable radio-telephone.

During the major campaigns, manpower for the various disciplines and tasks was scheduled at staggered intervals, to the extent possible. This avoided overtaxing accommodation and transportation facilities (principally the helicopter).

1.5 QUALITATIVE ANALYSES

1.5.1 General

The collection of environmental data from the Gunnar tailings areas and surrounding environment has involved the collection of a wide range of quantitative data. Firstly, the site has been characterized as to its topography by an on-site survey. Key reference points were surveyed and elevations of installations such as piezometer nests were accurately determined. The solids both on the surface of the tailings, within, and underlying the tailings were characterized as to their physical and chemical nature. Meteorological data were collected from both battery operated on-site recorders and from equipment transmitting data several times daily to a satellite. Stream flow data and the chemistry of the water leaving the site were recorded, thus enabling a mass balance on both stable elements and radionuclides to be calculated. To evaluate the material leaving the tailings by aqueous routes, porewater samples were collected from within the tailings and under and around the tailings, and waste rock areas. Data collection was such that its precision and accuracy could be estimated and its limitations for modelling or evaluation could be understood. This section describes, in general terms, the approaches and techniques used to ensure that the data presented are of reasonable quality. This description enables the reader to determine the data uncertainty so that the user can separate the variables depending upon the end use. This discussion is broken down into the general areas of meteorological, physical, and chemical data. More detailed discussions are presented in the appropriate appendices to this report. Chemical analyses and analytical techniques are discussed in more detail in Volume 2, Appendix 1.

1.5.2 Meteorological and Radiometric Data

All meteorological and climatic data, along with the radiological data measured during the atmospheric studies, were carefully reviewed. As the meteorological data were retrieved at frequent intervals via the satellite, they could be continuously reviewed and thus verify the equipment operation. Rudimentary calibration for all instruments was carried out prior to start-up in December and therefore anomalous behaviour was easily identified.

The only problems experienced were the failure of the rainfall gauge to register correctly when initially installed and a temperature sensor failure in April. The rainfall gauge was returned to Saskatoon for service and redeployed, in working shape, in May. The temperature sensor was also replaced in early May, leading to the loss of only 3 weeks of temperature data at the 2 m height; the 10 m sensor continued to function properly.

Similar reviews of the Terradex and gamma TLD data were also undertaken. These reviews resulted in re-evaluation of some data by Terradex. For the most part no substantial errors were found and the data which was outside of the suggested range was accepted as accurate. Subsequent repeat measurements using duplicate or short term samples confirmed the distributions of concentrations found in the initial testing. The data are consistent with anticipated trends for seasonal variations and spatial variations occur on a repeatable basis.

1.5.3 Physical Data

Physical data collection consisted of survey control for various sample locations and elevations, depth measurements for below grade sample recovery, sample recovery and transportation, and physical laboratory testing. The procedures and their related QA/QC are discussed in detail in the appropriate appendices.

The project timing did not permit obtaining a current set of air photos and as a result, 1976 photos had to be used for preparing ground contours. Current ground survey controls were established, however, to be used in conjunction with the 1976 photography. Permanent on-site benchmarks were established with an assumed elevation of 100.000 m and a closed traverse of horizontal control points was established around the site. This benchmark and the control points were used for all horizontal and vertical survey control. The survey subcontractor visited the site before and during both major field campaigns to tie in sample locations. For sample points established after March 19, 1986, the sampling personnel were used for survey control. The use of a closed traverse of control points substantially reduces the potential for survey errors.

Depth measurements for soil samples were reasonably accurate and reflect the method of sampling used. To recover a sample, casing had to be both inserted and withdrawn from the ground, thus providing a double check on depth. Soil interfaces were not precise, however, because of the method of drilling. The accuracy is therefore dependent on the frequency of sampling and observations of drilling advancement. Accepted procedures for preventing contamination of samples during the sampling process were used throughout. The one area of possible concern would be the tailings solids samples recovered using the casing sampler. This sampler could not be completely cleaned between sample recoveries.

Handling of soil and water samples was facilitated by the use of a universal numbering system and a special coordinator for this portion of the work. An inventory of each day's samples was prepared in Uranium City every night. Samples were shipped directly to BBT's laboratory in Saskatoon from where they were distributed to the various testing laboratories. Transmittal sheets were used for all inter-laboratory sample movement. No problems were experienced at any stage with lost or unidentified samples.

As much as possible, all physical laboratory tests were performed in accordance with ASTM procedures. Where deviations from the standard procedure were used, the deviations have been noted and their significance commented upon. For tests on disturbed samples (moisture content, Atterberg limit, specific gravity and grain size), duplicate tests were performed by different laboratories and/or different operators. In all cases, the results gave good agreement.

The physical tests with the largest potential source of error were those requiring undisturbed samples, notably hydraulic conductivity and density. Both the tailings and underlying soils were very sensitive, the drilling equipment was very limited in its ability to recover samples, and the amount of handling of samples was substantial. These factors contributed to sample disturbance and hence to potential errors.

To offset this problem, each of the foregoing tests was performed by 4 different procedures and on a large number of samples. The ranges shown for these tests are therefore considered representative, although the accuracy of any individual test is difficult to assess. The procedures and expected accuracy for these 2 tests are discussed in detail in Volume 4, Appendix 3.

1.5.4 Chemical Data

Chemical analyses were carried out on a wide range of environmental materials including tailings solids, the tailings porewater in contact with these solids, the surface waters draining the tailings, the porewater in contact with the geological materials underlying the tailings, and vegetation growing on and in the immediate proximity of the tailings. All of these different environmental compartments, comprising a wide range of environmental matrices, were analyzed for major and trace stable elements and radionuclides of the U-238 and TH-232 decay series.

The focus of the analytical effort was the tailings porewater. This component received the majority of the quality control and quality assurance effort because of a series of factors including: 1) accessibility of the sample locations on a year round basis, so that one particular location could be repeatedly sampled over the duration of the program; 2) the tailings porewater contains the highest mobile inventory of both radionuclides and trace elements, and is the most important component (in conjunction with the solids) for assessing long-term environmental significance; and, 3) the tailings porewater contains relatively high levels of substances such as sulphate and iron which are known to interfere with analyses of certain elements and cause sample changes in the field, and thus should result in the highest levels of sampling and analytical variability.

The tailings porewater location N1C was sampled on every field trip. Such sampling established the temporal variability factors in a relatively stable area and permitted calculation of an overall uncertainty distribution for this type of data. The factors contributing to temporal variability include seasonal factors, but also the longer term changes associated with the physical and chemical disturbance of the area of the tailings being sampled. In addition to sequential field program sampling, samples were collected from the same hole sequentially during the same sampling program, to determine the range of variability associated with sequential sampling from the same location and essentially the same time. Samples were also collected, mixed, and then split between laboratories to determine the range of interlaboratory variability or accuracy. Samples were also collected and split so that blind replicates could be submitted to the same laboratory to ascertain the degree of laboratory precision. Lastly, the laboratories involved split samples themselves to determine, on known duplicates, the degree of variability for their own internal quality control program.

These data are presented in tables in the various technical appendices. The reader should interpret these as the use of the data dictates. These quality control analyses, including all of the above categories, amounted to about 30 percent of the total analyses undertaken (see Volume 2, Appendix 1).

In addition to these quality control cross-checks, the data was scrutinized to determine its reasonableness. For all aqueous samples, this procedure included the calculation of an electroneutrality balance. If the balance based upon the equivalents of major cations and anions was off by more than 5 percent, the laboratory was requested to recheck their calculations and repeat the analyses if necessary. In many cases, errors were found or repeat analyses resulted in a better balance. The corrected data are presented on the data sheets included in the appendices to this report. In some of the cases, repeat analyses and calculation checks still resulted in an unsatisfactory balance, leaving the cause of the imbalance unresolved. The latter situation applies for only a small percentage of the samples, however.

In some instances, discrepancies in data reported for blind replicates between laboratories were traced to inconsistencies in reporting format. This has been noted and corrected in the data tables. In other cases, principally in the trace element analyses, certain pieces of data (for example, manganese collected from Test Hole No. N2C on December 1985 and sent as a blind replicate) would produce a value that was confirmed by the laboratory but geochemically does not follow a consistent pattern. In this particular instance, the ratio of manganese to iron was used as an internal check because of their relatively consistent behaviour under oxidizing and reducing conditions. Values like this (Mn 420 mg/l) are left in the data set because they are the 'best' data available. It is recommended that these outliers be accounted for, if the data are to be used for modelling or other quantitative purposes.

In other instances, such as for stable lead, there is a consistent difference in the data between the check laboratory test and the main laboratory. These data are internally consistent, as the blind replicates and internal quality control and assurance data show, and are presented in the data tables as reported after inquiry by the project team. As the discrepancies for a couple of trace elements could not be resolved during the course of the program, a set of certified standards blended into a tailings porewater matrix was sent to each of the laboratories for analyses. These data are discussed in Volume 2, Appendix 1 and should be used when interpreting the data.

Generally, for these matrix types and analytical techniques, an inspection of the data suggests the uncertainty associated with the major anions and cations is about 30 percent at the parts per million or low parts per thousand levels. At the low parts per billion range, the uncertainty is larger being about a factor of 2 to 5. The radionuclide levels were lower than normally found in porewater for uranium mine tailings. The overall uncertainty associated with the analyses is about 100 percent at the 1 Bq/l level, although the within laboratory precision was better. At levels near the detection limit for the radionuclide concerned, the accuracy was poorer.

The data necessary for a statistical evaluation of the accuracy and precision are available in the appendices, but no statistical analyses have been carried out. Any statistical analysis of the data set should be carefully planned to derive the type of data necessary for future use of this information. Volume 2 provides an outline of all the analytical and quality control procedures followed by the laboratories participating in this study, with the routine detection limits claimed by those laboratories. Standard analytical procedures were followed throughout this study in order that the data generated can be directly compared with other similar data. Data presented as part of the QA/QC program provide information as to both the accuracy and precision of this data, and by inference applies to other data collected and analyzed in a similar manner.

1.6 SUMMARY OF DATA

1.6.0 Overview of Quantitative Data Collection Program

The NUTP was instituted as part of a societal need to understand the long-term environmental impact of uranium mill tailings, as they have been or will be abandoned.

The NUTP has been split into 3 administrative sections, as follows: 1) the development of fundamental understanding of the chemical and physical processes that occur within the tailings by both field and laboratory investigation; 2) the development of mathematical models based upon the understanding of fundamental processes of mobilization, transport and environmental effect; and, 3) the investigation of the potential role of technologies in modifying mobilization and transport processes to reduce environmental effects to acceptable levels. This section of the summary report describes the general nature of the field studies undertaken to supply an integrated data base for the abandoned Gunnar Mine mill tailings site over a specified time period. This site was selected for evaluation because it consisted of non-sulpuric, neutral tailings located in Western Canada. The integrated field studies included the collection of meteorological, geotechnical, geochemical, hydrogeological, hydrological, and biological data.

The following subsections provide a brief overview of the sampling plans, procedures and data collected. As the amount of data is large, it is presented in several separate volumes, numbered 2 to 10, Appendices 1 to 9.

1.6.1 Meteorological and Air Quality Data

To evaluate the significance of water and wind-mediated mobilization and transport processes, meteorological data on air temperature, wind direction and speed, and precipitation were collected (see Photograph No. 1.2). All of these data were collected with a high degree of reliability and are summarized in Table 1.2 on the basis of monthly averages. Air temperature at 10 m height above ground ranged from -42°C in January and February to 35°C in June and July. The site is exposed, with maximum wind speeds being relatively constant, varying from a low monthly maximum of 35 km/h in June to a high monthly maximum of 50 km/h in February. Precipitation was recorded on site from May of 1985 to the end of September, 1985. Rainfall during this period amounted to 142 mm. Snow cores collected on the tailings in late March indicated a winter snow pac available for tailings groundwater recharge on the order of 130 mm. Winter precipitation was greater than this as sublimation of the winter snow pac in February and March was expected to be significant. The closest meteorological station, located at Uranium City north of Lake Athabasca, has shown an average annual precipitation of 344.8 mm with 197.9 mm occurring as snow and 204.9 mm as rainfall. This would suggest that snow pac measurements based upon a 10:1 water equivalent accounted for most of the snowfall but some rainfall during the fall period was not recorded. Uranium City data indicated 20 mm of rain in October is normal, however, exposure can cause variations in the meteorological and climate parameters.

Radon gas emanating from the tailings, waste rock and surrounding area was measured (see Photograph No. 1.3). Radon levels in the tailings and waste rock pore spaces are within the expected range for uranium mill tailings (20,000-80,000 pCi/l) and waste rock (200-400 pCi/l). Radon flux from the tailings and waste rock was determined using mat and can techniques, with checks being made for mat edge effects to ensure that no significant leakage was occurring. These radon flux measurements can be used for the calculation of radon dose both on the tailings and downwind. To provide a cross-check for potential off-site exposure and off-site modelling predictions ambient air levels of radon were measured off-site using Track Etch detectors at a 1 m elevation above ground. High readings were traced to off-pile tailings that had been naturally revegetated and covered by a new layer of soil and litter in the 21 years that have elapsed since abandonment.

PHOTOGRAPH NO. 1.2

Meteorlogical Tower

PHOTOGRAPH NO. 1.3

Radon Mat Site

TABLE 1.2
SIGNIFICANT MONTHLY METEOROLOGICAL VALUES

Month	Data Capture (%)	10m Temperature (°C)		Maximum Wind		No. of Days With Winds > 20 km/hr	No. of Days With Rain	Rain Depth (mm)
		Minimum	Maximum	Speed (km/hr)	Direction (°)			
Dec. '84	*	-50	+2	36	90°	18	NA	-
Jan. '85	100	-42.6	+6.1	42.9	104°	12	NA	-
Feb. '85	99	-42.6	3.7	49.9	90°	18	NA	-
Mar. '85	98	-31.6	14.3	37.4	80°	20	NA	-
Apr. '85	77	-16.7	17.8	48.2	38	20 out of 23	NA	-
May '85	99	- 3.4	29.6	44.1	89	26	4	2.8
Jun. '85	99	- 0.6	35.8	34.7	341	21	6	38.3
Jul. '85	99	4.5	35.5	37.2	285	26	11	39.1
Aug. '85	100	3.3	33.9	33.5	113	21	11	52.6
Sep. '85	100	- 4.9	26.0	44.7	316	22	9	26.7

* - Tower started working Dec. 9, 1984, 2130 GMT, Data reported is after tower moved.

NA - Not available, instrument out of service until May 3, 1985.

+ - One week of data loss due to processing error at receiving station.

On the Gunnar Main Tailings area, there is evidence of wind erosion with dune migration evident on the eastern side. During the winter months, elevated areas on the tailings surface are frequently blown clear of snow, and dust plumes can be noted around these exposed areas. The lack of on-site power precluded the use of high volume dust samplers. To provide data for calculating atmospheric dust loadings, surface grain size distribution and moisture content were measured. During the late winter, snow core samples were collected around the exposed areas on the tailings and the quantity of windblown dust that had been trapped in the snow layers over the winter was measured. This will provide near-field calibration data for wind generated dust in the winter months.

In addition to radon gas and dust emissions, the tailings and waste rock area emit ionizing radiation. Because of their low penetrating power, alpha and beta radiations were below detection limits at a 1 m height above the ground. Gamma radiation levels were measured as mR/h on the main tailings areas and waste rock area. Data from Gunnar Main ranged from 100-300 mR/h at 1 m above ground level to 300-600 uR/h, at ground level during the winter, to 300-600 uR/h and 300-700 uR/h, respectively in the summer. This small difference between winter and summer is suspected of being due to limited shielding by ice and snow. Radiation levels recorded on the waste rock were consistently around the 150 uR/h level, regardless of height. A total of 73 spot measurements were carried out on the waste rock pile and only 10 percent of these recorded radiation levels greater than 1 mR/h at a 1 m height.

The detailed meteorological, air quality and radiation data collected as part of this study are presented in Volume 3, Appendix 2.

1.6.2 Tailings Solids and Surrounding Soils

The fieldwork for the tailings solids and surrounding soils portion of the study was conducted in conjunction with the installation of monitor wells for the groundwater component. The selection of test hole locations was, therefore, made to provide the best areal coverage possible to satisfy both requirements.

The initial concept for the fieldwork as contained in the proposal was to use a track-mounted auger drill mobilized by barge. The contract was not awarded until after freeze-up in late October 1984, however, and as a result this method of drilling had to be abandoned. In addition, the possibility for an overland winter road to be constructed to Uranium City in 1985 was uncertain and in any event the timing would have been too late. Various types of aircraft-mobilized drilling equipment were considered in conjunction with the Scientific Authority and it was decided to use a locally available, vibratory drill which could be moved by helicopter.

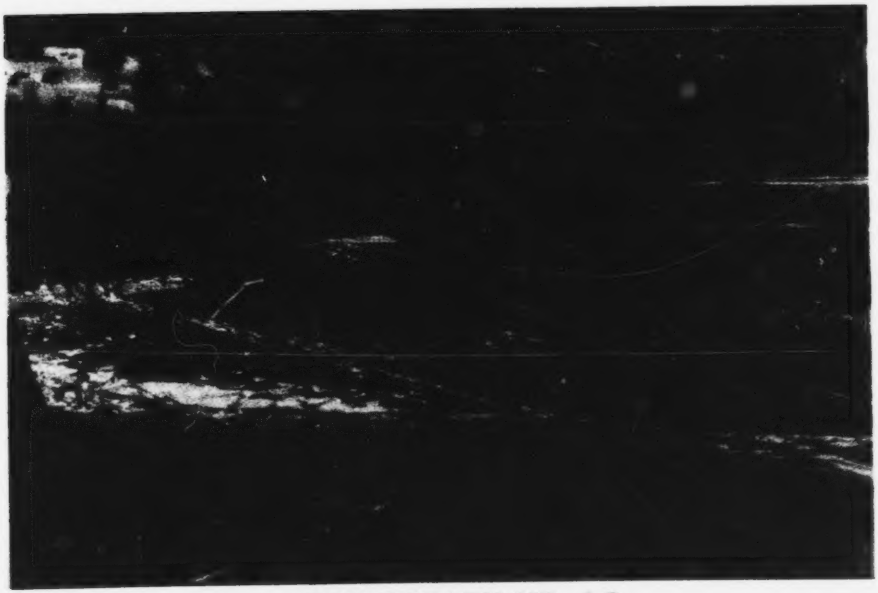
The vibratory drill was able to complete an adequate number of test holes to satisfy the project objectives within the project budget. The disadvantages of the drill were that a complete stratigraphic log of the test holes was not possible and the types of piezometer installations was restricted. Mechanical problems with the drill affected the number of installations in some of the campaigns. Photograph Nos. 1.4 and 1.5 show the drilling equipment in transit.

Fieldwork was performed in 3 campaigns in November 1984, March 1985 and June 1985. The vibratory drill was used for the November and March campaigns. Hand auger equipment was used for the June campaign. Table 1.4 in Section 1.6.3 presents a summary of all the test holes, and the location of the test holes is shown on the drawings in Volume 4, Appendix 3. In summary, 65 test holes were drilled with the drill rig, for an approximate total depth of 420 m. In addition, 25 test holes were dug or augered by hand.

PHOTOGRAPH NO. 1.4

Moving the drill with the helicopter.

November 1984



PHOTOGRAPH NO. 1.5

Moving the support equipment to a new site.

March 1985

All samples were usually logged in the field, placed in suitable containers, labelled and shipped to Saskatoon for distribution to the various testing laboratories. Geotechnical testing was performed by BBT and consisted of moisture content, density, Atterberg limit, grain size, triaxial, consolidation, and permeability tests. Geochemical and radionuclide testing was performed by BEAK Analytical Laboratories and Saskatchewan Research Council. Two samples were also tested for rare earths by X-ray Assay Laboratories Ltd.

The field and laboratory information obtained is presented on the appropriate tables and figures in Volume 4, Appendix 3. Enclosed with this summary are typical examples of a test hole summary form (Figure No. 1.6), grain size distribution curve (Figure No. 1.7), and tailings solids analysis (Table 1.3).

The general stratigraphy encountered, in descending order, consisted of tailings, organic materials, lacustrine clayey silts or silty clays, and bedrock. The depth of tailings varied up to greater than 14 m at Gunnar Main, 3 to 4 m at Gunnar Central, and 2 to 4 m in Langley Bay. Peat or organic clay was often noted at the interface between the tailings and native soil. The underlying soil was basically a silty clay or clayey silt. The thickness of this deposit also varied considerably from 0.5 to 9.4 m at Gunnar Main, 3 to 6 m at Gunnar Central, and 8 m to greater than 16 m in Langley Bay. Bedrock was defined as abrupt casing refusal. A typical cross-section through Gunnar Main is shown on Figure No. 1.15 in Section 1.6.8.

The tailings graded from a fine to medium, poorly graded sand near the spigot location on Gunnar Main, to silty sand, to silt, to silty clay with increasing distance from the spigot. There was also a tendency for increasing fineness with depth. Gunnar Main was primarily poorly graded (SP) sand at the south side, grading to silty sand and silt at the north side. Gunnar Central was predominantly silty sand and silt. The Langley Bay Tailings were predominantly silt and silty clay with only minor amounts of silty sand.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Langley Bay
LOCATION ID: N5A
SITE COORDINATES:
N 2990
E 4009
GROUND ELEVATION (m) 70.78

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: McNeill
COMPLETION DATE: 84/12/08
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 16.31

WELL OWNER NUTP
INSTALLER G. Bell
INSTALLATION DATE 84/12/08
CASING ELEV. (m) 71.16
CASING LENGTH (m) 12.05
CASING DIAMETER (m) 0.035

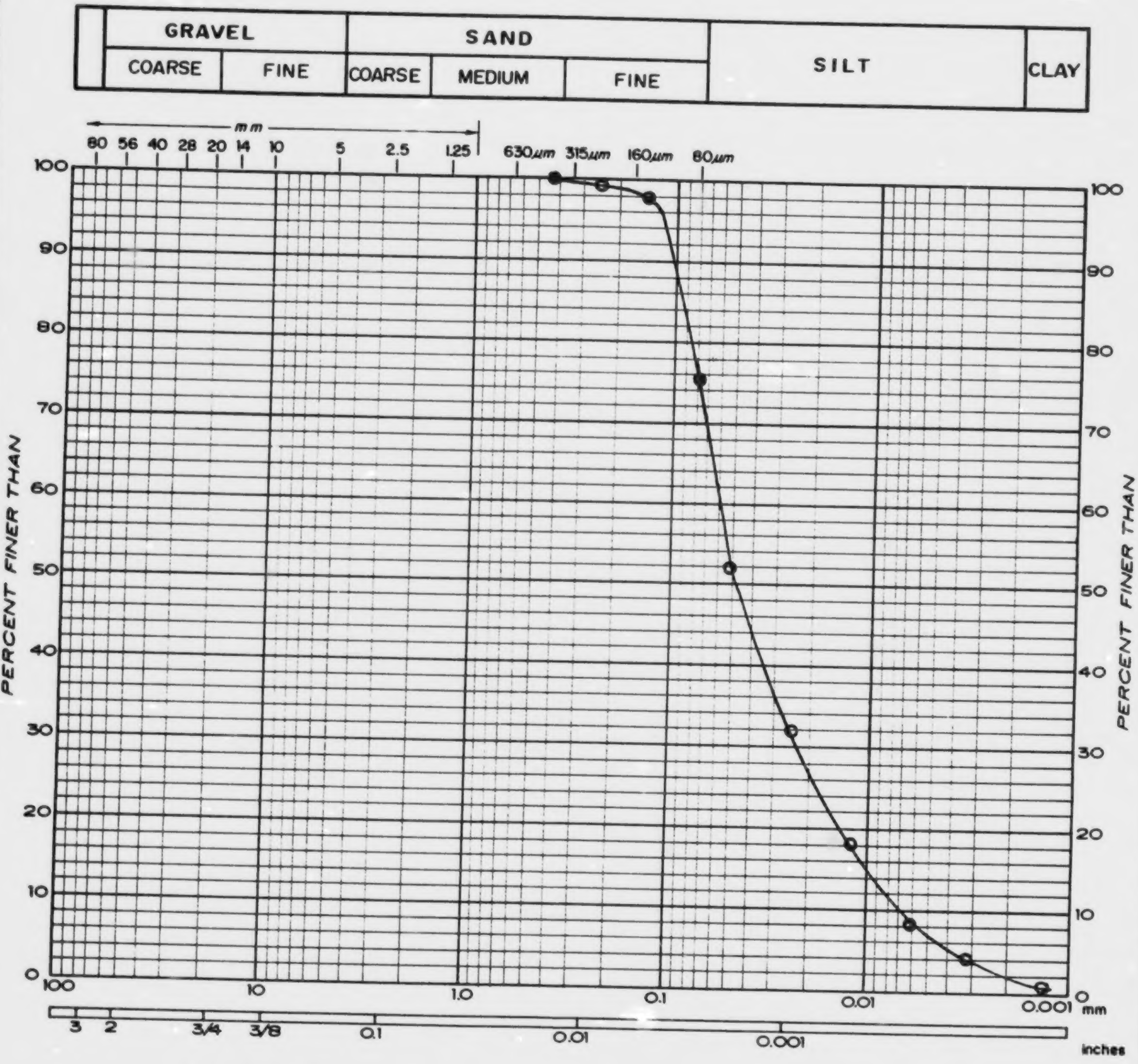
FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Clay
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 11.67
OPEN / SCREEN LENGTH (m) 0.127
OPEN / SCREEN AREA (m²) 0.0203

0.38 m

LITHOLOGICAL SUMMARY

DEPTH ft		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S1B		ML	37.3	1145			SILT, moist, firm, low plastic med. reddish brown, frost to 0.46 m.
		1						
5	S2B		ML	31.9	1151			As above, trace of sand.
		2						
	S3B		ML	34.9	969	24.6	31.9	As above, trace of clay.
10		3						
	S4B		ML	50.7		NP	NP	Water was about 2.45 m. As above, non-plastic.
			OL					ORGANIC sand at about 3.51 m
		4	CI	Tailings Interface				CLAY, moist, stiff, med. plastic, med. grey
15	S5B		CI	64.5				As above, med. grey
		5						
	S6B		MH	58.1		42.0	50.6	SILT, highly plastic, med. grey
		6						

FIGURE NO. 1.6



TAILINGS

$D_{60} = 0.06$ mm $D_{30} = 0.023$ mm $D_{10} = 0.0069$ mm

REMARKS: SILT - moist, firm, low plastic, medium reddish brown

BBT Geotechnical Consultants Ltd.
BBT GEOTECHNICAL CONSULTANTS LTD

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N5A Depth 1.2 to 1.8m
Sample No: S2

FIGURE NO. 1.7

TABLE 1.3 TAILINGS SOLIDS ANALYSIS, LANGLEY BAY N5

Location	Langley Bay							Langley Bay						
Depth from Surface	2.1 to 2.7 m							3 to 3.7 m						
Parent Material	Silt, reddish brown tailings							Silt, reddish brown tailings, organic						
Field Code	N5A (S3A)							N5A (S4A)						
Date	84.12.08							84.12.07						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter														
pH of Leach Water	5.1							4.8						
IC Scan (Anions):														
Bromide	L 54	-	-	-	-	-	L 54	L 30	-	-	-	-	-	L 30
Chloride	290	-	-	-	-	-	290	133	-	-	-	-	-	133
Fluoride	16.2	-	-	-	-	-	16.2	9.0	-	-	-	-	-	9.0
O-Phosphate	L 54	-	-	-	-	-	L 54	L 30	-	-	-	-	-	L 30
Sulphate	152,000	-	-	-	-	-	152,000	46,000/ 46,000	-	-	-	-	-	46,000/ 46,000
Nitrate	L 54	-	-	-	-	-	L 54	L 30	-	-	-	-	-	L 30
Major Cations:														
Magnesium	560	1.75	31,000	96.9	420	1.31	32,000	610	2.54	22,000	91.7	1,400	5.83	24,000
Calcium	49,000	98.4	780	1.57	65	0.13	49,000	15,000	79.4	2,000	10.6	1,900	10.1	18,900
Iron	53	0.12	43,000	96.2	1,600	3.58	44,700	14	0.03	39,000	93.3	2,800	6.70	41,800
Manganese	23	4.20	520	94.9	5	0.91	548	58	12.0	400	82.5	27	5.57	485
Silica SiO_2	880	0.18	1,870	0.38	490,000	99.4	493,000	700	0.12	700	0.12	590,000	99.8	591,000
Aluminum	125	0.15	23,000	28.0	59,000	71.9	82,100	42	0.05	24,000	28.9	59,000	71.1	83,000
Sodium	830	1.57	1,010	1.91	51,000	96.6	52,800	370	10.5	950	2.69	34,000	96.3	35,300
Potassium	108	1.22	1,430	16.2	7,300	82.6	8,840	157	0.79	4,300	21.7	15,300	77.3	19,800
Trace Cations:														
Strontium	54	62.8	20	23.3	12	14.0	86	24	14.4	45	27.0	98	58.7	167
Lead	31	7.49	360	87.0	23	5.56	414	7.8	4.73	131	79.4	26	15.8	165
Cobalt	1.1	8.80	10.4	83.2	1	8.0	12.5	1.8	11.0	9.5	58.3	5	30.7	16.3
Nickel	2.2	12.6	14.3	81.7	1	5.71	17.5	1.8	7.83	18.3	79.6	3	13.0	23
Zinc	1.1	1.80	56	91.8	4	6.56	61	1.2	2.40	84.0	82.4	7	14.0	50

TABLE 1.3 TAILINGS SOLIDS ANALYSIS, LANGLEY BAY N5

Location	Langley Bay							Langley Bay						
Depth from Surface	2.1 to 2.7 m							3 to 3.7 m						
Parent Material	Silt, reddish brown tailings							Silt, reddish brown tailings, organic						
Field Code	N5A (S3A)							N5A (S4A)						
Date	84.12.08							84.12.07						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	3.3	6.88	38	79.2	7	14.6	48	1.2	1.97	41	67.2	19	31.2	61
Copper	4.3	6.94	56	90.3	2	3.23	62	2.4	9.60	22	88.0	1	4.0	25
Cadmium	L 1.1	-	13.6	100	L 2	-	13.6	L 0.6	-	7.2	100	L 2	-	7.2
Barium	6.5	1.14	530	92.7	35	6.12	572	7.2	1.05	500	72.7	181	26.3	688
Vanadium	3.2	5.33	53	88.3	4	6.67	60	1.5	1.00	140	93.3	8	5.33	150
Titanium	27	0.97	230	8.24	2,530	90.7	2,790	9.0	0.31	470	15.9	2,470	83.7	2,950
Arsenic	0.33	2.68	12	97.6	-	-	12.3	1.02	2.13	47	97.9	-	-	48
Selenium	0.05	9.26	0.49	90.7	-	-	0.54	L 0.03	-	0.36	100	-	-	0.36
Molybdenum	9.8	62.0	6.0	37.9	L 2	-	15.8	4.2	36.5	7.3	63.5	L 2	-	11.5
Beryllium	L 0.54	-	4.5	81.8	1	18.2	5.5	L 0.30	-	3.8	100	L 1	-	3.8
Total Sulphur (%)	-	-	-	-	-	-	L 0.01	-	-	-	-	-	-	L 0.01
Total Carbonate (%)	-	-	-	-	-	-	L 0.01	-	-	-	-	-	-	0.01
Sum Anions	3,170	-	-	-	-	-	-	961	-	-	-	-	-	-
Sum Cations	2,550	-	-	-	-	-	-	824	-	-	-	-	-	-
Radionuclides														
Uranium (ug/g)	0.0039	0.005	31	38	-	-	82//25	-	-	-	-	-	-	-
Thorium-230 (Bq/g)	0.0021	0.014	8.5	57	-	-	15//8.5	-	-	-	-	-	-	-
Radium-226 (Bq/g)	0.0264	0.075	7.5	21	-	-	35//7.5	-	-	-	-	-	-	-
Lead-210 (Bq/g)	0.7209	1.8	25	63	-	-	40//25	-	-	-	-	-	-	-
Polonium-210 (Bq/g)	0.0177	0.07	14	56	-	-	25//14	-	-	-	-	-	-	-
Radium-228 (Bq/g)	0.0016	0.4	.11	28	-	-	0.4//0.11	-	-	-	-	-	-	-
LOI %							3.4							5.7

The laboratory hydraulic conductivity results for the tailings varied from 1E-03 to 1E-06 cm/sec with the higher values representing the coarser areas.

The native clayey silts and silty clays were generally saturated with relatively low shear strengths. The material varied from low to highly plastic, depending on the silt content. The laboratory permeability values for these materials varied from 1E-06 to 1E-10 cm/sec.

The test holes which penetrated into naturally deposited soils all were terminated in clay. Because of the presence of the clay as well as timing and budget constraints, it was decided on the advice of The Scientific Authority not to proceed with drilling of the Precambrian bedrock.

At the sampling locations, where piezometer intake screens were to be placed for sampling tailings porewater, tailings solids samples were also collected for chemical characterization. The concentration in the tailings porewater is the concentration that discharges to the surface during infiltration and discharge events, and thus it is important to understand the solids chemistry which in turn determines the porewater concentration. Three components of tailings solids were looked at as part of this study, and a typical analysis sheet is shown as Table 1.3. The first component is the water soluble fraction which provides an indication of the readily mobilized material under continued porewater flushing. Calcium sulphate and chloride were water soluble, along with a high percentage of the trace elements, strontium, cobalt, cadmium and molybdenum. This distribution undoubtedly reflects the mobilization of these particular elements during the acid leach in the milling process and their precipitation as sulphates or hydroxides in the tailings. The second component is the acid soluble component which reflects that fraction of the tailings material which was mobilized during the initial acid leach in the mill, but reprecipitates in the tailings in a form such as hydroxide which is not readily water soluble. This inventory is expected to be more mobile under local acidic conditions.

The final residue remaining after the water soluble and acid soluble material had been analyzed is the material which is locked up in an acid insoluble matrix, such as feldspar or silicate mineral. This material would be considered to be relatively stable from a geochemical standpoint and only released to the environment as a result of long-term weathering processes.

1.6.3 Groundwater

The Gunnar groundwater characterization study concentrated on groundwater sampling, field and laboratory chemical analyses of these samples, static water level measurements, and field response (slug) tests. All the monitor wells (piezometers) were on the Gunnar Main, Gunnar Central and Langley Bay tailings piles, or along the periphery of the waste rock pile. Wells were not installed in the Precambrian bedrock underlying the tailings or in the areas adjacent to the piles, due to minimal need and other priorities. The locations and depths of wells were chosen to allow an assessment of lateral and vertical hydraulic and chemical gradients, groundwater velocities and recharge/discharge conditions.

The fieldwork for the groundwater portion of the study was conducted in conjunction with the test drilling and soil sampling for the tailings solids component. As discussed in the previous section, the initial concept for the fieldwork as contained in the proposal was to use a track-mounted auger drill mobilized by barge. Because of timing problems, however, this method of drilling had to be abandoned. Various types of aircraft-mobilized equipment were considered in conjunction with the Scientific Authority and it was decided to use the locally available vibratory drill which could be moved by helicopter.

The vibratory drill was able to complete an adequate number of installations to satisfy the project objectives within the project budget. The disadvantages of the drill were that a complete stratigraphic log of the test holes was not possible and the type of piezometer installations was restricted. Mechanical problems with the drill affected the number of installations in some of the campaigns. Fieldwork was performed in 4 campaigns in November 1984, March 1985, June 1985 and August 1985. The vibratory drill was used for installations during the November and March campaigns only. Hand auger equipment was used for installations in June and August. In summary, 77 monitor wells were installed, with a total installed length of 284.5 m.

The monitor wells consisted of a modified Casagrande drive-point piezometer with 35 mm inside diameter riser pipes. All the monitor wells were located on Gunnar Main, Gunnar Central and Langley Bay Tailings, and along the periphery of the waste rock pile. Well tips were all installed in the tailings or the soil underlying the tailings.

Monitor well locations were concentrated on the Gunnar Main Tailings since the areal extent and thickness of the tailings was much greater than the other 2 tailings areas. Because of the variation in elevation and grain size distribution, it was felt that the largest variation in porewater movement, hydraulic conductivity and geochemistry would be found in this area. Table 1.4 presents a summary of all test holes and monitor wells which were installed.

After installation of piezometers, water levels were monitored during each major field campaign and approximately biweekly through the winter of 1985. Because of the logistics of site visits, routine water level measurements were difficult to obtain.

TABLE 1.4

TEST HOLE AND WELL INFORMATION

Location Identification	Northing (m)	Easting (m)	Relative Elev. (m) Ground	Relative Elev. (m) Casing	Top of Pipe Above Ground Surface (m)	Completion Depth Below Ground Surface (m)	Total Depth of Drilled Hole Below Ground Surface (m)
N1A	1230	3883	106.64	-	Hole Collapsed	Hole Collapsed	7.62
N1B	1231	3883	106.64	107.25**	0.56	3.70	6.10
N1C	1232	3883	106.50	106.88**	0.38(T)	9.67	11.89
N1D	1233	3883	106.29	106.89**	0.60	5.53	7.62
N1E	1227	3890	106.64	106.87	0.23	7.79	13.9
N1F	1227	3890	106.64	107.01	0.37(T)	4.15	4.9
N2A	1336	3702	101.83	102.07**	0.24	4.42	5.49
N2B	1336	3701	101.78	102.06**	0.28	5.72	5.49
N2C	1336	3701	101.79	101.94**	0.15	2.33	2.59
N2D	1336	3700	101.79	101.87**	0.08	1.63	1.83
N2E	1342	3700	101.81	102.17	0.36	7.60	19.6
N2F	1342	3701	101.81	102.29	0.48(T)	5.57	12.2
N2G	1342	3701	101.81	102.24	0.43	5.39	9.9
N2H	1342	3702	101.81	102.13	0.32	3.13	3.3
N2I	1342	3702	101.81	102.18	0.37	2.19	3.0
N2J	1342	3702	101.81	-	No Well	No Well	1.04
N3A	1900	4052	98.59	99.72/ 98.97**	1.13/ 0.38*	2.91	Installed by Vibration
N3B	1900	4052	98.62	99.85/ 98.98**	1.23/ 0.36*	2.81	Installed by Vibration
N3C	1900	4053	98.63	99.60/ 99.04**	0.97/ 0.41*	2.3±	Installed by Vibration
N3D	1899	4053	98.64	99.67/ 99.04**	1.03/ 0.40*	1.01	Installed by Vibration
N3E	1899	4056	98.77	99.03**	0.26	13.35	19.17
N3F	1899	4055	98.78	99.03**	0.25	7.98	8.38
N3G	1898	4054	98.74	99.02**	0.28	2.58	3.96
N4A	2585	4361	83.21	83.59**	0.38	5.41	5.79
N4B	2584	4361	83.08	83.50**	0.42	3.87	4.27
N4C	2585	4362	83.15	83.51**	0.36	2.33	1.98
N4D	2586	4362	83.22	83.98**	0.76	1.28	1.07
N5A	2990	4009	70.78	71.16**	0.38	11.67	16.31
N5B	2990	4009	70.75	71.17**	0.42	3.36	3.35
N5C	2990	4010	70.75	71.12**	0.37	2.10	2.13
N6A	1634	3905	99.87	100.37**	0.50(T)	11.00	11.25
N6B	1634	3905	99.90	100.38**	0.48	5.15	5.20
N6C	1634	3905	99.90	100.23**	0.33	3.93	4.0
N6D	1635	3904	99.89	100.42**	0.53	2.97	3.0
N6E	1635	3903	99.88	100.31**	0.43	1.95	2.0

TABLE 1.4 (continued)

Location Identification	Northing (m)	Easting (m)	Relative Elev. Ground (m)	Relative Elev. Casing (m)	Top of Pipe Above Ground Surface (m)	Completion Depth Below Ground Surface (m)	Total Depth of Drilled Hole Below Ground Surface (m)
GM1A	1537	4107	104.35	-	No Well	No Well	No Drilling
GM2A	1426	3928	104.10	-	Thermistors Inst.(T)	5.27	8.4
GM2B	1427	3928	104.10	104.55	0.45	6.97	7.0
GM2C	1425	3928	104.10	104.45	0.35	3.82	3.85
GM2D	1425	3928	104.10	-	No Well	No Well	1.3
GM3A	1214	3631	101.98	-	Thermistors Inst.(T)	4.40	19.8
GM3B	1214	3631	101.98	102.36	0.38	9.90	Installed by Vibration
GM3C	1215	3632	101.98	102.50	0.52	4.14	4.6
GM3D	1215	3632	101.98	102.58	0.60	4.28	4.6
GM3E	1216	3633	101.98	102.48	0.50	4.36	4.6
GM4A	1632	3815	100.92	-	Thermistors Inst.(T)	4.20	4.8
GM4B	1631	3815	100.98	101.38**	0.40	4.67	4.6
GM4C	1632	3815	100.92	-	No Well	No Well	1.22
GM5A	1519	3819	101.46	-	No Well	No Well	No Drilling
GM6A	1543	3863	101.68	101.98	0.30(T)	4.15	11.0
GM6B	1542	3863	101.68	102.10	0.42	2.80	2.8
GM6C	1543	3863	101.68	-	No Well	No Well	1.37
GM7A	1370	3616	99.94	100.61**	0.67	2.0±	Installed By Vibration
GM8A	1673	4034	101.36	-	No Well	No Well	No Drilling
GM9A	1658	4107	101.44	-	No Well	No Well	4.65
GM9B	1658	4107	101.44	101.81	0.37(T)	4.10	4.10
GM9C	1657	4107	101.41	101.71**	0.30	3.54	3.6
GM10A	1171	3988	109.69	-	No Well	No Well	No Drilling
GM11A	1071	3751	104.10	-	No Well	No Well	No Drilling
GM12A	1197	3428	100.95	101.22	0.27	3.00	3.6
GM12B	1197	3428	100.95	101.35	0.40	1.77	1.8
GM13A	1444	3466	100.60	100.92	0.32	6.86	9.8
GM13B	1444	3467	100.60	100.98	0.38	3.12	3.2
GM17A	1781	3893	99.71	-	No Well	No Well	7.15
GM17B	1781	3894	99.68	100.02**	0.34	3.30	3.4
GM17C	1780	3894	99.60	99.95**	0.35	1.80	1.8
GM18A	1430	3678	100.34	–	No Well	No Well	No Drilling

TABLE 1.4 (continued)

Location Identification	Northing (m)	Easting (m)	Relative Elev. (m) Ground	Relative Elev. (m) Casing	Top of Pipe Above Ground Surface (m)	Completion Depth Below Ground Surface (m)	Total Depth of Drilled Hole Below Ground Surface (m)
GM19A	1563	3667	101.24	-	No Well	No Well	3.9
GM19B	1563	3667	101.00	101.65**	0.65	3.70	3.7
GM19C	1563	3668	101.41	101.99**	0.58	2.47	2.5
GM20	1550	3870	100.0±	-	Test Pit	No Well	1.43
GM21	2082	4185	99.9±	-	0.1	0.90	1.00
GM22	1270	4136	104.5±	-	0.2	0.80	0.90
GM23	1646	4200	99.5±	-	0.1	0.90	1.00
GM24	1648	4366	98.5±	-	0.1	0.90	1.10
GM25	1670	3938	99.2±	-	No Well	No Well	No Drilling
GC5A	2596	4400	83.11	-	No Well	No Well	9.8
GC5B	2597	4400	83.11	83.35	0.24	3.10	4.0
GC5C	2597	4400	83.11	83.43	0.32	3.81	4.4
GC6	2560	4546	82.9±	-	No Well	0.02	No Drilling
GC7	2630	4405	82.1±	-	No Well	0.01	No Drilling
GC8	2628	4340	82.2±	-	No Well	0.01	No Drilling
LB2A	2813	3877	69.89	-	No Well	No Well	19.8
LB2B	2813	3877	69.89	70.24	0.35	3.59	3.6
LB2C	2813	3878	69.89	70.29	0.40	3.38	4.2
LB3A	3192	4154	69.84	70.22	0.38	1.40	1.4
LB3B	3192	4154	69.84	-	No Well	No Well	13.1
LB3C	3191	4154	69.84	70.24	0.40	3.60	3.7
LB7A	3119	4105	69.89	-	No Well	No Well	11.3
LB7B	3119	4105	69.89	70.24	0.35	4.10	4.2
LB7C	3119	4106	69.89	70.22	0.33	2.13	2.2
WR1	465	4555	69.0±	-	0.1	0.90	1.00
WR2	465	4727	72.8±	-	0.1	0.90	1.00
WR3	622	4790	72.5±	-	0.1	0.90	1.00
WR4	718	4750	73.8±	-	0.3	0.80	0.90
WR5	750	5030	72.0±	-	0.1	1.00	1.10

* Cut Back From Original Length on 03/08/85.

** Elevations Surveyed. Remaining Elevations Were Calculated By Adding the Pipe to the Ground Elevation.

± Elevations were estimated from the contour plans.

(T) - Thermistor String Installed.

Hydraulic conductivity tests were performed by carrying out response tests (slug tests) on monitor wells using Hvorslev's rising head method. The tests were performed either when the wells were initially installed or when piezometers were flushed prior to geochemical sampling.

Water samples were collected during 4 campaigns, December 1984, March 1985, June 1985 and August 1985. Two sets of samples were collected for most monitor wells, while some had 3 sets collected. Water samples were generally collected from the wells using a varistaltic pump in the winter and a stainless steel bailer in the summer. Conductivity, temperature, alkalinity, and pH of the samples were determined in the field prior to acidification and transport. During the winter campaigns, the water sampling was conducted inside an insulated hut (Photograph No. 1.6) set over the monitor well being sampled. Field properties were measured after return to Uranium City at night. The summer campaigns were undertaken from a camp set up on site and field properties were measured in a field laboratory (Photograph No. 1.7).

PHOTOGRAPH NO. 1.6

Groundwater sampling in hut November 1984.

PHOTOGRAPH NO. 1.7

Groundwater sampling in June 1985.

The sampling program was conducted under the direct supervision of BBT Geotechnical Consultants Ltd. The following laboratories were used for the laboratory testing program:

Chemical - IEC BEAK Consultants Ltd., Mississauga, Ontario
Radionuclides - Saskatchewan Research Council, Saskatoon, Saskatchewan
Check Tests & Replicates - Monenco Consultants Limited, Calgary, Alberta

Figure Nos. 1.8, 1.9(a) and 1.9(b) present typical slug test and groundwater sampling record forms. Table 1.5 provides a typical example of the results of the groundwater analysis.

As rainfall and snowmelt infiltrate the main tailings area at Gunnar, they dissolve a portion of the water soluble species in the tailings, principally calcium sulphate along with associated elements and minerals. This solute fraction of water infiltrating into the tailings solids achieves a chemical equilibrium until the water discharges to a geochemically different groundwater regime or a surface water.

The upper Gunnar Main tailings area is located in the Old Mudford Lake Basin. The granite bedrock underlying the lake basin has a very low intrinsic permeability, although there is a major structural feature running under the lake and down through a valley to a second small tailings pond called Gunnar Central. Borings through the tailings and into the material underlying the original Mudford Lake bed showed this material to be a silty clay. Examination of the valley connecting Gunnar Main and Gunnar Central showed this same silty clay present. Borings in the Gunnar Central and Langley Bay tailings areas, and the waste rock areas all showed this same silty clay which in the area of the waste rock pile, showed evidence of being varved. This clay which, showed an insitu permeability on the order of 1E-06 to 1E-10 cm/s forms a tight physical and geochemical seal under all of the tailings and waste rock areas. Consequently, virtually all water contaminant transport through the series of 3 tailings areas occurs as surface flow or as very shallow groundwater flow.

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GM17C

SLUG VOLUME (litres): Approx. 0.75

INITIAL WATER LEVEL (at t_o): 0.99

DATE 06/21/85

TIME : 5:15 P.M.

DEPTH (m from top of casing) 2.15

STATIC WATER LEVEL

DATE: 06/21/85 TIME : 5:15 P.M.

DEPTH (m from top of casing) 0.99

OPEN INTERVAL (m) 1.80 to 1.93

Height Above Ground (m) 0.35

WELL DIAMETER (m) 0.035

FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from to)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_o or $\frac{H-h}{H-H_o}$
0	2.15	1.16		
1	2.13	1.14		
2	2.11	1.12		
4	2.06	1.07		
9	1.99	1.00		
1027	0.97	-0.02		

REMARKS: Recovery Test

FIGURE NO. 1.8

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: N3 EF
SAMPLE ID B1 to B3
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 84/12/07
SAMPLING TIME:
Start 11:00
Finish 14:45

FINAL FIELD VALUES

	Surface	Down Hole
pH (S.U.)	6.67	
Ec (umhos/cm)	3100	
Eh (millivolts)		
TEMP. (°C)	11 (1)	
ALKALINITY (mg/l $CaCO_3$)	444 @ 4.52	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	–	–	–	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
One litre			
150 ml			
50 ml			
SPECIFY OTHERS: 200 ml	B2	B1	0.5 HNO_3
250 ml		B3	0.5 HNO_3

REMARKS: 1.6 Acid Lot #4093
Used 1 Filter
Combined N3E & N3F. Mostly N3E.

FIELD REP(S): Meays

FIGURE NO. 1.9(a)

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$		SAMPLING INFORMATION	
DEPTH TO WATER (h_2) (m)	7.70 (E)	WITHDRAWAL METHOD	Peristaltic
DEPTH OF WELL (h_1) (m)	13.74 (E)	SAMPLING METHOD	Filtered
WELL DIA. (m)	0.035	FILTER SIZE	0.45 µ
BORE VOLUME (m^3)		THERMOMETER I.D.	
DEPTH TO SCREEN (m)	13.35 (E)	Ec/pH/Eh METER ID's	301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 14:00

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	84/12/13	84/12/14	
METHOD OF SHIPMENT	Hand	Hand	
SAMPLE CLASSIFICATION	B1 & B2	B3	

NOTES: (1) The water had warmed in the hut and the sample testing was done at this temperature.

N3EF 84/12/07

FIGURE NO. 1.9(b)

TABLE 1.5: EXAMPLE GUNNAR GROUNDWATER QUALITY DATA FROM LOCATION N1, PIEZOMETERS C AND E

Location		SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main
Depth from Surface		9.7 m	9.7 m	9.7 m	9.7 m	9.7 m	7.8 m	7.8 m
Parent Material		Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings
Field Code		N1C (alternate lab blind replicate)	N1C (blind field sequenced)	N1C (alternate lab blind replicate)	N1C (alternate lab blind replicate)	N1C (alternate lab blind replicate)	N1E	N1E
Date		84.12.10	84.12.10	85.03.10	85.06.20/24	85.08.24	85.03.29	85.06.20/24
Parameter								
pH:	Laboratory	7.8	-	6.9 (7.99)	6.8 (8.03)	7.4 (7.97)	7.2	7.7
	Field	6.88	-	-	-	-	-	-
Acidity ($CaCO_3$) (mg/L)		-	-	180 (201)	144 (27)	- (L 1)	16/13	11
Alkalinity ($CaCO_3$) (mg/L):	Laboratory	565/610	-	840	570 (646)	570 (563)	143	119
	Field	767	-	-	-	-	-	-
Conductivity (umhos/cm):	Laboratory	5,600	-	5,800 (5,550)	5,000	5,900/5,800 (5,760)	3,200	2,800
	Field	5,500	-	-	-	-	-	-
Total Dissolved Solids (105°C) (mg/L)		5,500	-	6,000 (5,880)	6,000 (6,400)	- (1,370)	3,200	3,300
DOC (mg/L)		680	-	14 (12)	7.5 (L 1)	8 (3)	44	1.0
DIC (mg/L)		480	-	150 (46)	110 (170)	161/151 (160)	75	21/22
Kjeldahl-N (mg/L)		-	-	1.68	2.40	-	1.02	0.40
Major Anions (mg/L):								
Bromide		L 1	-	0.1	-	0.4 (0.15)	L 0.5	L 1
Chloride		220/220	-	330 (320)	270/280 (339)	300 (313)	8.9/8.6	5.5
Fluoride		1.6	-	1.0/0.7	0.6/0.7 (0.86)	1.4 (0.86)	1.9	1.2
Sulphate		2,700	-	3,300 (3,420)	3,100/3,200 (3,430)	3,300 (3,350)	2,200/2,100	2,100
Nitrate		1	-	L 0.2	-	1.4	L 1	-
Major Cations (mg/L):								
Magnesium		550 (640)	680	720 (740)	660//640 (672)	719 (710)	290/290	250//250
Calcium		420/410 (630)	590/480	520 (530)	480//430 (516)	500/500 (409)	530/540	470//450
Iron		123 (120)	157/132	69 (59)	44/43 (34)	40 (34)	3.5	2.2
Manganese		36 (420)	37	47 (38)	41 (34)	40 (44)	7.8	8.5
Silica SiO_2		36	48	50/49 (26)	46/51 (26)	- (2.6)	22	27
Aluminum		0.29 (1.0)	0.33	0.45 (0.05)	1.1//0.81 (0.01)	0.81 (0.017)	0.58/0.58	1.1//0.76
Sodium		156/140 (130)	185/175	200 (210)	197//196 (198)	192/176 (202)	54/55	52//52*
Potassium		20/17 (17)	24/22	19.1 (14)	16//17.0 (16)	17.1/15.6 (16)	11.2/10.9	6//5.8
Trace Cations (mg/L):								
Strontium		1.80	2.4	2.5 (2.1)	2//2.7 (1.6)	2.6 (2.1)	1.53/1.54	1.4//1.47
Lead		0.20 (0.06)	0.66	0.24/0.20 (L 0.005)	0.33 (L 0.005)	0.55 (0.003)	0.17	0.27
Cobalt		0.05 (0.021)	0.14	0.11/0.10 (0.20)	0.16 (0.014)	0.24 (0.024)	0.05	0.08

TABLE 1.5: EXAMPLE GUNNAR GROUNDWATER QUALITY DATA FROM LOCATION NI, PIEZOMETERS C AND E

Location	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main
Depth from Surface	9.7 m	9.7 m	9.7 m	9.7 m	9.7 m	7.8 m	7.8 m
Parent Material	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings
Field Code	NIC (alternate lab blind replicate)	NIC (blind field sequenced)	NIC (alternate lab blind replicate)	NIC (alternate lab blind replicate)	NIC (alternate lab blind replicate)	NIE	NIE
Date	84.12.10	84.12.10	85.03.10	85.06.20/24	85.08.24	85.03.29	85.06.20/24
Parameter							
Nickel	0.04 (0.033)	0.12	0.07/0.07 (0.034)	0.05 (0.083)	0.065 (0.024)	0.03	0.03
Zinc	0.160 (0.10)	0.200	0.170 (0.036)	0.110 (0.18)	0.090 (0.016)	0.080	0.060
Chromium	0.01 (0.035)	0.06	0.04/0.04 (0.024)	0.04 (0.072)	0.050 (0.036)	0.03	0.04
Copper	0.010 (0.003)	0.025	0.030/0.030 (0.038)	0.020 (0.009)	0.020 (0.003)	0.025	0.020
Cadmium	0.015 (L 0.001)	0.050	0.050 (0.003)	0.025 (L 0.001)	0.030 (L 0.001)	0.015	0.020
Barium	0.06 (0.12)	0.07	0.02 (0.069)	L 0.05//0.04 (0.017)	0.03 (0.012)	L 0.01/L 0.01	L 0.05//0.03
Vanadium	0.02 (0.13)	0.03	0.03 (0.11)	L 0.05//0.04 (0.09)	0.04 (0.15)	0.03/0.02	L 0.05//0.03
Titanium	0.30 (0.01)	0.36	0.32 (0.006)	- (L 0.001)	- (L 0.001)	0.41	-
Arsenic (ug/L)	64	64	72/66 (110)	-	-	10	-
Selenium (ug/L)	L 0.5	L 0.5	-	-	-	-	-
Molybdenum	0.08 (0.08)	0.09	0.08 (0.05)	0.2//0.13 (0.01)	0.14 (0.078)	0.14/0.16	0.2//0.13
Beryllium	L 0.01 (0.023)	L 0.01	L 0.01 (0.008)	L 0.05//L 0.01 (0.004)	L 0.01 (0.005)	L 0.01/L 0.01	L 0.05//L 0.01
Sum Anions+	74.1 (-)	-	94.8 (100.8)	83.5	88.5 (89.8)	47.8	46.2
Sum Cations	72.8 (90.1)	(91.0)	97.9 (97.0)	90.1	92.5 (88.0)	53.5	46.5
Tritium (T.U.)	-	-	-	-	-	124	-
Radionuclides							
Uranium (ug/L)	2,300/2,600	2,600	8,000 (7,400)	8,400	8,300 (8,300)	1,950	4,500
Thorium-230 (Bq/L)	0.16/1.7	0.75	-	-	0.03 (0.04±0.01)	-	-
Radium-226 (Bq/L)	2.1/4.5	2.6	3.0 (2.44±0.12)	3.0	2.5 (1.95±0.10)	1.4	-
Lead-210 (Bq/L)	L 0.3/1.5	2.3	1.5 (2.75±0.15)	0.9	5.0 (1.1±0.1)	1.7	-
Polonium-210 (Bq/L)	0.4/0.26	1.4	0.25 (1.35±0.04)	-	-	0.02	-
Radium-228 (Bq/L)	L 0.1/0.25	L 0.1	-	-	-	-	-
Thorium-232 (Bq/L)	-	-	-	-	L 0.02	-	-
Thorium-228 (Bq/L)	-	-	-	-	L 0.02	-	-

L = Less than.
( ) Alternate lab blind replicate.
* Average value.
/ = Internal replicate.
// = Acid preserved bottle analysis//wet bottle unpreserved analysis.
+ = Electroneutrality balances: anions on unpreserved bottles; cations on preserved bottles.

The permeability of the sandy fractions of the tailings is on the order of 1E-03 cm/s and this grades to on the order of 1E-06 cm/s in the fine tailings. There is considerable variation in the major chemical constituents of the tailings, with finer fractions generally containing more of the chemical precipitates than the coarser materials. This grain size correlation, however, has been altered considerably in many areas by recharge and discharge patterns, and the associated precipitation of salts with evaporation of water.

The general pattern of groundwater flow is for meteoric waters (rainfall and snowmelt) to infiltrate the tailings raising the water table and creating a hydraulic discharge to the surface in low lying areas. This water dissolves principally calcium and magnesium salts along with associated trace elements and radionuclides, and these flow as surface water out of the Gunnar Main basin and into Gunnar Central where, depending upon the season and elevation of the water table in Gunnar Central, overland flow may occur. At other times of the year, the runoff may seep into the head of the tailings area causing a hydraulic discharge at the other end and a surface flow down into the Langley Bay tailings area. Because of the pattern of salt precipitation and disolution, and the associated iron redox chemistry, the chemistry of the water discharging from the outlet of Gunnar Central to Langley Bay may be significantly different from the surface water entering the top of Gunnar Central.

The most significant radionuclide in the porewater is Ra-226. The total solids analyses suggest that all of the radionuclides are present at close to secular equilibrium, with the obvious exception of uranium. The higher levels of Ra-226 in the porewater may be related to its association with sulphate complexes of magnesium and calcium. Thorium, lead and polonium are suspected of being tied up principally with the acid soluble complexes of magnesium such that when the pH drops and magnesium values rise due to the solubilization of the salt, the values of thorium-230, lead-210 and polonium-210 also rise (e.g. N1C).

The physical flow system in the tailings thus transports meteoric waters from recharge to discharge areas and dissolves a series of major cation salts along with trace elements and radionuclides. These elements then precipitate principally in discharge areas with evaporative concentration. The precipitation of iron in discharge areas causes the pH to drop, which causes a preferential rise in porewater concentrations of magnesium, along with other elements which are relatively insoluble under neutral to basic conditions. A series of these processes occurs across the tailings area as water seeps into the tailings in some areas and dicharges in others. The surface water flux to Langley Bay of these major and trace elements and radionuclides is discussed in the surface water section.

1.6.4 Surface Water

All of the surface water runoff from Gunnar Main discharges to the north through a small bedrock gap, into a marshy area (Frog Pond), and then down through a steep-sided bedrock valley and into Gunnar Central. During the drier months, water seeps into Gunnar Central or evaporates from the surface, and if there is an excess of water, it discharges over a bedrock lip and down through one of 2 stream channels to Langley Bay. Depending upon water levels in the section of Langley Bay open to Lake Athabasca and the section cut off from the larger portion of Langley Bay, flow from Gunnar Central may flow into "cutoff" Langley Bay or directly into the open portion of Langley Bay. Flow into the cutoff section of Langley Bay then gradually exchanges with the open section of Langley Bay and the open section of Langley Bay, exchanges with Lake Abathasca.

In order to estimate the surface runoff from Gunnar Main tailings area and a small beaver pond (Photograph No. 1.8) located just below it, a weir was constructed in December 1985 in the bedrock valley between Gunnar Main and Gunnar Central (Photograph No. 1.9). Measurements at the weir began at the end of April when snow melt started. The majority of the snow melt occurred during the first week in May, and 60 percent of the total runoff measured during the monitor period (until the end of August 1986) occurred during this time. Figure No. 1.10 shows the rainfall and runoff from Gunnar

Main to Gunnar Central measured during the study period. The pattern shows a very rapid runoff response to snow melt in early May, following which there is a gradual drop-off in discharge suggesting a slow lowering of the water table in the catchment area in late May and June. A couple of days of rain in mid-June onto an almost fully saturated tailings produced a rapid runoff response. Intermittent rain in July and August produced only slight changes in runoff as most of this rain soaked into the tailings. Where runoff did occur, the hydraulic response was very rapid.

In addition to surface runoff, data flow proportional water samples were collected for chemical analysis. The chemistry of this water after the initial snow melt reflected to a large degree, a hydraulic displacement of tailings porewater with some rainwater dilution. Table 1.6 shows some typical runoff water quality data.

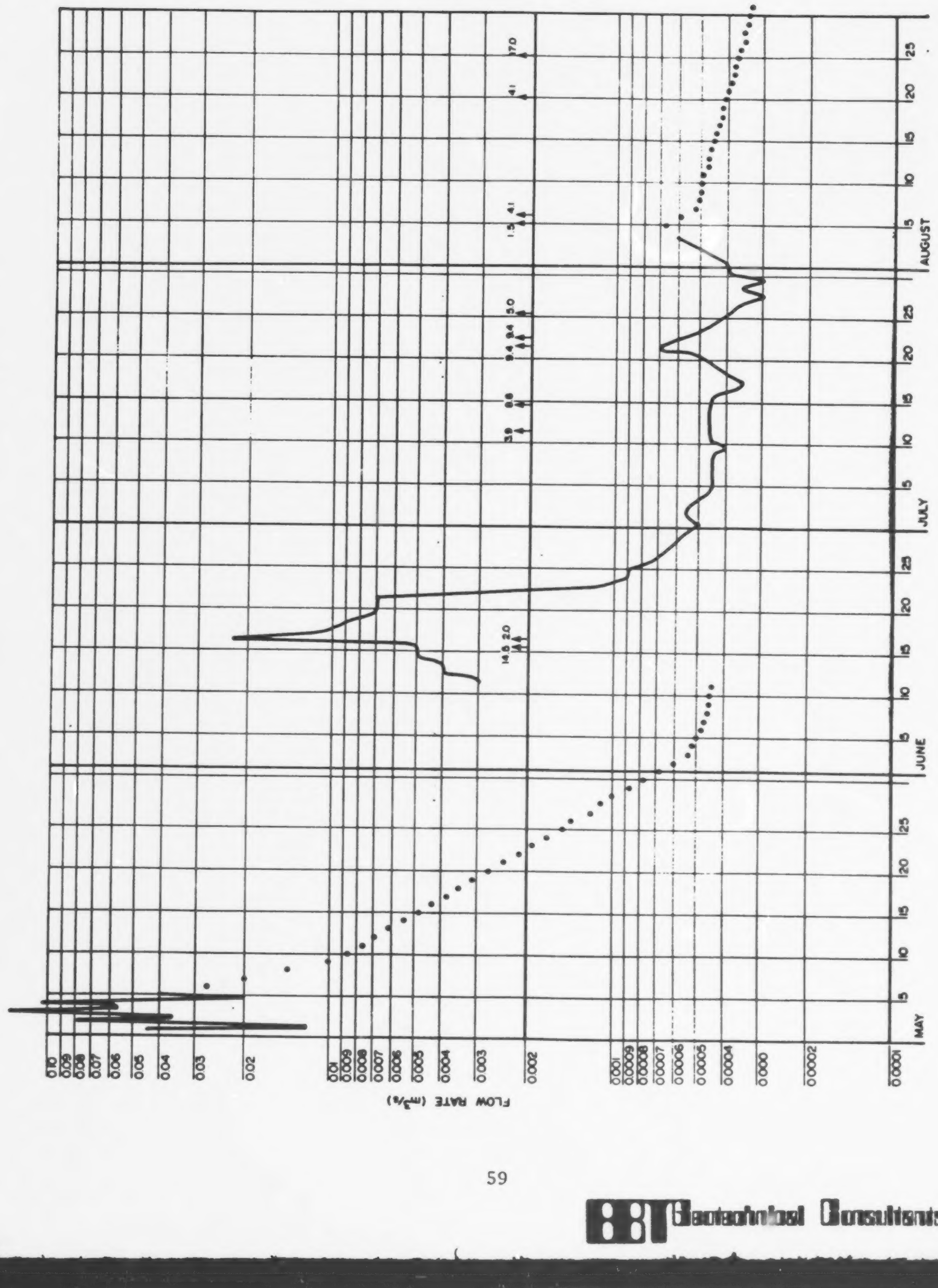
Although water quality runoff from Gunnar Central to Langley Bay was not measured as part of this study, samples collected by Environment Canada showed that, like the runoff from Gunnar Main, runoff from Gunnar Central during the summer reflects a hydraulic displacement of tailings porewater, and this flow discharges down to a small channel connecting cutoff and open sections of Langley Bay. Depending upon water levels in Lake Athabasca, flow may move into the cutoff section of Langley Bay or out into the open portion of Langley Bay. Because of the lower rate of water exchange with Lake Athabasca, concentrations of tailings constituents are higher in the cutoff section of Langley Bay than in the open section. Water level recorders were installed in both the cutoff section of Langley Bay and the open section in order to record water level differences and hydraulic exchange rates between the 2 portions of the Bay. Bathynetic maps of Langley Bay were constructed in order that volumetric calculations and water exchange rates with Lake Athabasca could be calculated. Despite the rather small channel leading to Lake Athabasca, these exchange rates were found to be significant with a calculated hydraulic exchange rate being on the order of 2 weeks.

PHOTOGRAPH NO. 1.8

Beaver dam on outlet between Gunnar Central and Gunnar Main.

PHOTOGRAPH NO. 1.9

Weir on outlet between
Gunnar Central and Gunnar Main.



SURFACE WATER RUNOFF
FROM GUNNAR MAIN

FIGURE 1.10

TABLE 1.6

EXAMPLE OF SURFACE WATER QUALITY DATA AT WIER (MAY TO JUNE)

Parameter	May W1	May W2	May-30 Run 1	May-30 Run 2	06 June	07 June	08 June	12/13 June	22 June	22 June
pH			7.2	7.7	7.4	7.6		7.5	7.7	
Conductivity (umhos/cm^2)			1,090	1,210	1,900	1,950		2,000	2,300	
Acidity ($CaCO_3$, mg/L)										
Alkalinity ($CaCO_3$, mg/L)					27	25		35	49	
Total Dissolved Solids (mg/L)					1,870	1,880		1,950	2,300	
Volatile Dissolved Solids (mg/L)										
TIC (mg/L)										
TOC (mg/L)					27			29	34	
Total Kjeldahl N (mg/L)					1.17			1.15	1.48	
Ammonia-N										
Nitrite-N (mg/L)										
Nitrate-N (mg/L)					0.06/0.09			0.03/0.03	0.07/0.16	
Total Phosphate (mg/L)										
IC Scan:										
Fluoride			0.1	0.1	0.4	0.4		0.3	0.4	
Chloride			28	35	60	74		70	84	
Nitrite			L 1	L 1	L 2	L 5		L 0.5	L 1	
O-Phosphate			L 1	L 1	L 0.1	L 5		L 0.5	L 1	
Nitrate			L 0.1	L 0.1	L 0.2	L 0.5		L 0.2	L 0.2	
Sulphate			560	650	1,090	1,040		1,140	1,400	
DCP Scan:										
Beryllium	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01		L 0.01	L 0.01	L 0.01	L 0.01
Molybdenum	0.02	0.01	0.01	0.01	0.03		0.02	0.03	0.02	0.03
Calcium	121	105	94	108	194		188	200	220	220
Vanadium	L 0.01	L 0.01	L 0.01	L 0.01	0.01		0.01	0.01	0.01	0.01
Aluminum	0.38	0.71	0.56	0.40	0.32		0.33	0.24	0.25	0.57
Magnesium	102	98	72	92	180		172	183	210	200
Barium	0.02	0.02	L 0.01	L 0.01	0.02		0.09	0.02	0.03	0.04
Potassium	1.71	2.4	1.99	1.95	3.9		3.8	4.2	4.9	4.7
Strontium	0.32	0.28	0.24	0.27	0.48		0.46	0.49	0.52	0.51
Sodium	29	28	21	27	49		47	51	61	56
Zinc	0.015	0.010	0.025/0.030	0.010	0.020		0.030	0.020	0.025/0.030	0.045
Cadmium	L 0.005	0.005	0.010/L 0.005	0.010	0.010		0.005	L 0.005	L 0.005/0.005	0.005
Manganese	1.80	1.99	0.39/0.38	0.59	3.3		5.7	6.1	9.1/9.1	5.8
Cobalt	0.02	0.02	0.01/0.01	0.01	0.02		0.03	0.02	0.03/0.02	0.03
Copper	0.010	0.005	0.030/0.035	0.015	0.010		0.010	0.010	0.010/0.010	0.035
Silver										
Iron	0.88	1.07	1.01/1.01	0.82	0.60		0.84	0.72	1.40/1.40	2.0

TABLE 1.6 (continued)

Parameter	May W1	May W2	May-30 Run 1	May-30 Run 2	06 June	07 June	08 June	12/13 June	22 June	22 June
Lead	0.08	0.10	0.08/0.07	0.07	0.10		0.10	0.09	0.10/0.11	0.12
Chromium	0.01	0.01	0.01/0.01	0.01	0.02		0.02	0.02	0.02/0.01	0.02
Nickel	L 0.01	0.01	L 0.01/0.01	L 0.01	0.02		0.01	0.01	0.02/0.02	0.02
Silica (SiO_2)	6.3	9.6	8.0/8.0	6.9/7.4	13.9		14.3/14.1	14.1	22	20
Titanium	0.11	0.10	0.10/0.10	0.10	0.13		0.14	0.17	0.16	0.18/0.20
Uranium										
Boron	0.24	0.13	0.18	0.16	0.36/0.28		0.28	0.30	0.31	0.30
Selenium										
Arsenic					L 1		L 1	L 1	1/2	
Sum Anions					24.3	-	-	26.4	32.3	
Sum Cations					26.7	-	-	27.4	31	
% Difference					3.3	-	-	1.9	2.4	
Radionuclides:										
Total U (ug/L)	265	-	220	-	210	210	233	260	413	
Th-230 (Bq/L)	1.4	-	2.1	-	0.42	0.40	-	0.50	0.66	
Ra-226 (Bq/L)	1.83	-	4.1	-	0.52	0.73	0.63	0.71	1.93	
Pb-210 (Bq/L)	6.0	-	-	-	0.73	-	-	L 0.7	L 0.7	

1.6.5 Biology

A number of previous studies and reports have described aquatic and terrestrial biota of the Gunnar tailings and surrounding environment. Harms and Fraser (1982) describe plant communities on the tailings, giving frequency, abundance and percent cover for plant species in each community. Radmann and Frankling (1982) give a plant inventory and associated tailings chemistry. Kalin (1981) provides data on trace metal content of tailings vegetation, and associated chemistry of tailings and standing water. Kalin (1982) gives plant species densities and selected radionuclide contents (Ra-226, Pb-210), with additional data on chemistry of associated tailings. Tailings vegetation studies have concentrated on Gunnar Main, while also providing limited data for Gunnar Central and Langley Bay. Data on uranium and thorium isotopes in vegetation and vegetation biomass are lacking from previous reports, as are data of any kind from the Waste Rock Pile and the Frog Pond between Gunnar Main and Gunnar Central. These data may be important for validation of food chain transport and mass balance models.

Previous studies of aquatic biota in the Gunnar area include an EPS (1981) study in Langley Bay and Lake Athabasca, and Tone's (1982) SRC study of the Gunnar Flooded Pit and Lake Athabasca. The EPS report provides data on fish catch, fish radionculide contents (Ra-226, Pb-210, Th-230), associated water and sediment chemistry, plankton and benthic insect densities, and plankton biomass. Tone's report provides data on fish catch, fish radionuclide contents (Ra-226, Pb-210), associated water and sediment chemistry, and densities of benthic invertebrates, plankton and sediment bacteria. Comparable bacterial data for the tailings are lacking from past reports.

The biology component of the present study was designed to compile and evaluate existing data, and to augment these data with additional sampling and analysis in order to provide a more complete biological description of the Gunnar site. The 1985 field survey included collection and analysis of bacterial samples at various depths in 2 tailings cores, the description of vegetational communities and their distribution on the tailings, determination of above ground biomass in each community, collection and analysis of 19 vegetation samples for trace metals and radionuclides, and collection and analysis of 5 associated root zone soil samples for trace metals radionuclides and grain size. Radionculide analyses included U-238, Ra-226, Th-230, Th-232, Th-228 and Pb-210. Sampling sites included the Waste Rock Pile, Gunnar Main, the Frog Pond, Gunnar Central and Langley Bay, as well as several terrestrial control sites. Eighteen additional vegetation samples, collected in 1983 by M. Apps of the Northern Forest Research Station, were analyzed for trace metals and radionuclides as part of this study. Both in 1983 and 1985, vegetation and soil samples were archived for future use.

Additional water, sediment and fish samples recently collected by EPS for analysis of trace metals and radionuclides are described as part of this study, although analytical results were not available at the time of report preparation. Local terrestrial wildlife and wild food consumption habits of Gunnar area residents were determined by consultation with local residents and conservation authorities.

Tailings bacterial densities were determined in aerobic, anaerobic, sulphur-reducing, sulphur-oxidizing and iron oxidizing categories. Bacterial densities in all categories were higher in Langley Bay tailings than on Gunnar Main (Table 1.7). In both locations, aerobic bacterial maxima occurred at the tailings surface, and in the original lake sediments about 4 m below the surface, with minimum densities in the deepest tailings zone.

Anaerobic bacteria followed a similar pattern as on Gunnar Main, but showed no strong depth relationship to those on Langley Bay. Other bacterial groups achieved maximum density in the original lake sediments on Gunnar Main, or in the deep tailings on Langley Bay.

Vegetation communities on the tailings include a peripheral mesic shrub community, a grass and/or sedge community (depending on tailings moisture), a cattail or cattail-sedge community near standing water, and a mud-flat community on recently drained tailings. A xeric shrub community characterized the Waste Rock Pile. Dominant plant taxa and peak (August) biomass estimates for each community are shown in Table 1.8. The sedge community of the Frog Pond is the most productive and the xeric shrub community of the Waste Rock Pile is the least productive. Community distributions on the tailings are shown in Figure No. 1.11.

Community distributions are typically defined by clear demarkations between plant species groups, often related to tailings moisture or stability. Photograph No. 1.10 illustrates separation of mixed grass (Hordeum, Pucinellia) and foxtail (Hordeum only) in a line parallel to the edge of the standing water on Gunnar Main. Photograph No. 1.11 shows the 1/4 m^2 quadrant within which plants were clipped to constitute each biomass sample. Ten such samples were clipped, dried and weighed within each community.

The greatest radionuclide levels in above-ground vegetation were found in grasses near water and sedges on Gunnar Main (in particular Hordeum jubatum and Carex aquatilis), sedges and willow (Salix interior) on Langley Bay and the Frog Pond, and in cattails (Typha latifolia) near the Gunnar Flood Pit and the mouth of Zemel Creek. Lichens (Cladonia amouracraea) on rock ridges in the vicinity of Gunnar Main also contained high radionuclide levels, as did a single spruce sample (Picea mariana) with a high Ra-226 activity. Table 1.9 shows the range of radionuclide levels in dominant vegetation from each tailings area, based on the pooled set of samples from 1983 and 1985 vegetation surveys.

Radionuclide levels in root zone soils from each tailings area, based on the 1985 survey, are shown in Table 1.10. Bioaccumulation factors, based on analysis of 3 soil samples which correspond exactly to locations of analyzed vegetation samples, were on the order of 1E-02 to 1E-03 for U-238 and Ra-226, up to 1E-01 for Th-232 and Th-228, up to 1E-03 for Th-230 and approximately 1E-02 for Pb-210.

TABLE 1.7

BACTERIAL COUNTS IN GUNNAR TAILINGS

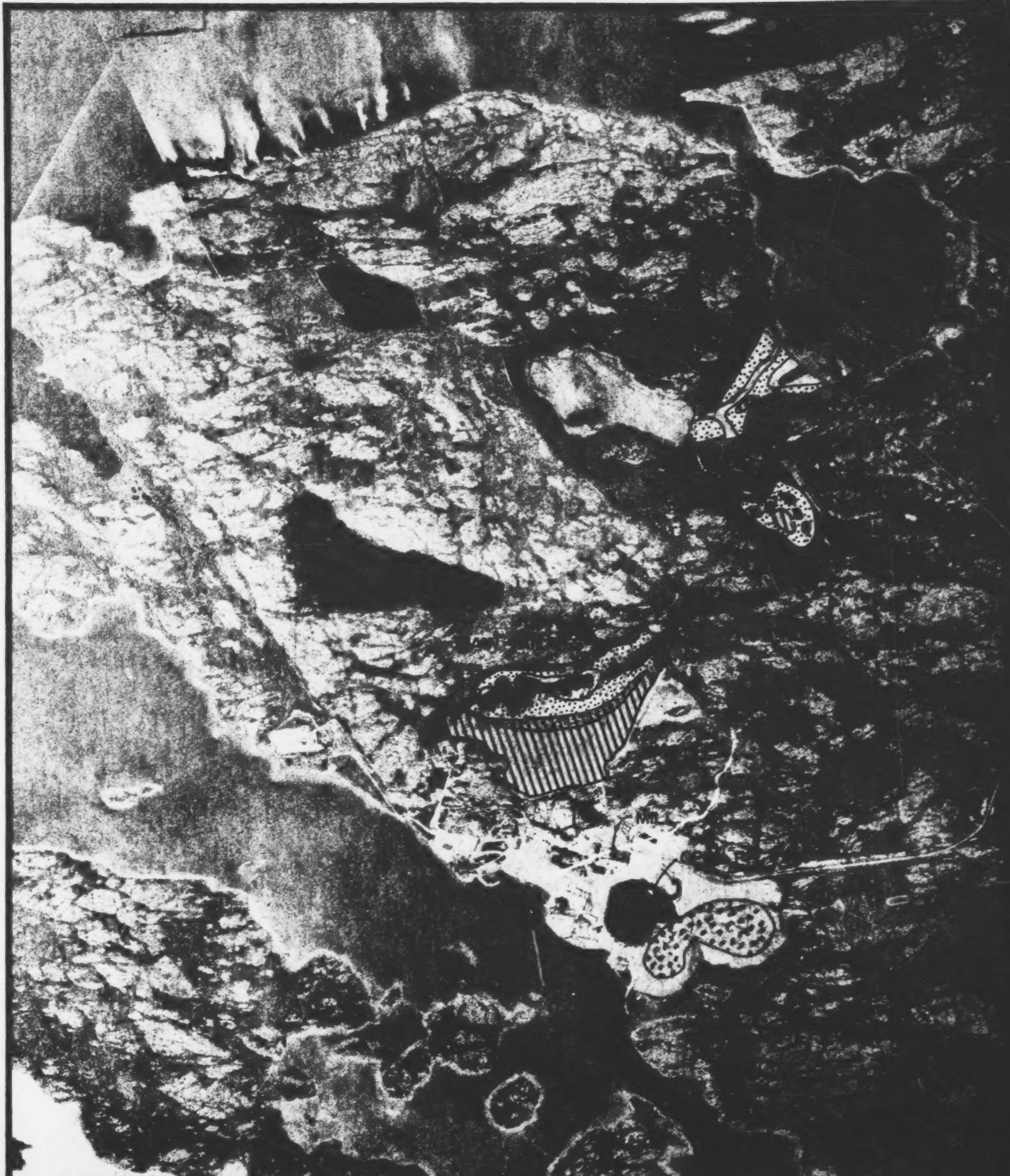
Sampling Location and Date	Core Hole Number	Sample Depth (m)	Soil Description	Aerobic Bacteria (bacteria/g)*	Anaerobic Bacteria (bacteria/g)*	Sulphate Reducing Bacteria MPN/g	Sulphur Oxidizing Bacteria MPN/g (95% Confidence Interval)	Iron Oxidizing Bacteria MPN/g
Gunnar Main (06.12.84)	N3E	0–0.03	Tailings (Red)	$4.8x10^2$	$4.9x10^3$	23 (7-70)	L 3 (-)	L 3 (-)
		1.06-1.22	Tailings (Red)	$1.4x10^2$	$3.3x10^2$	17 (5-46)	L 3 (-)	L 3 (-)
		2.44-2.74	Tailings (Red)	L 100	$3.9x10^2$	2 (L 0.5-7)	L 3 (-)	L 3 (-)
		4.42-4.57	Lake Sediment (Grey)	$3.3x10^2$	$2.1x10^3$	49 (17-130)	23 (4-120)	23 (4-120)
Langley Bay (24.03.85)	2B-1	0-0.20	Tailings (Reddish Brown)	$1.7x10^6$	$6.0x10^4$	$2.4x10^4$ (-)	L 3 (-)	9 (1-36)
	2B-2	0.13-0.45	Tailings (Reddish Brown)	$2.7x10^4$	$1.1x10^5$	$1.6x10^4$ $(6.4x10^3-5.8x10^4)$	230 $(40-1.2x10^3)$	$2.4x10^5$ $(1.5x10^4-4.8x10^5)$
	2C (2-2)	3.4	Tailings (Reddish Brown)	$5.5x10^3$	$9.9x10^4$	$3.3x10^3$ $(1.2x10^3-1.0x10^4)$	230 (70-700)	$9.3x10^3$ $(1.5x10^3-3.8x10^4)$
	2C (2-1)	3.9	Lake Sediment (Grey)	$2.1x10^6$	$1.6x10^5$	230 (70-700)	230 $(4-1.2x10^3)$	930 $(130-3.8x10^3)$

MPN = Mean probable number, estimated from numbers of positive tubes in dilution series (FDA, 1977).
(-) = Confidence interval could not be derived due to very low or high numbers.
* = Bacteria/g based on colony counts.
---- = Summer water table.

TABLE 1.8

VEGETATION BIOMASS IN GUNNAR TAILINGS AND WASTE ROCK AREAS

Location-Community	Dominant Taxa	Biomass (gm dry wt/m^2)
Frog Pond - Shrub	Alnus, Salix, Betula	101.25±77.14
Frog Pond - Sedge	Carex aquatilis	329.04±81.21
Langley Bay - Grass	Deschampsia, Pucinellia	125.8±266.1
Langley Bay - Shrub	Alnus, Salix, Betula	96.39±83.63
Langley Bay - Cattail/Sedge	Typha, Carex	226.21±77.73
Gunnar Main - Grass	Hordeum, Pucinellia	67.42±78.07
Gunnar Main - Shrub	Alnus, Salix, Betula	82.66±41.07
Gunnar Main - Mud Flat	Juncus	65.44±34.41
Gunnar Main - Cattail	Typha latifolia	118.17±82.13
Gunnar Central - Shrub	Alnus, Salix, Betula	93.66±65.51
Gunnar Central - Mud Flat	Juncus	41.54±46.89
Gunnar Central - Grass/Sedge	Calamagrostis, Carex	76.59±67.00
Waste Rock - Shrub	Salix, Populus, Rubus	18.66±21.37



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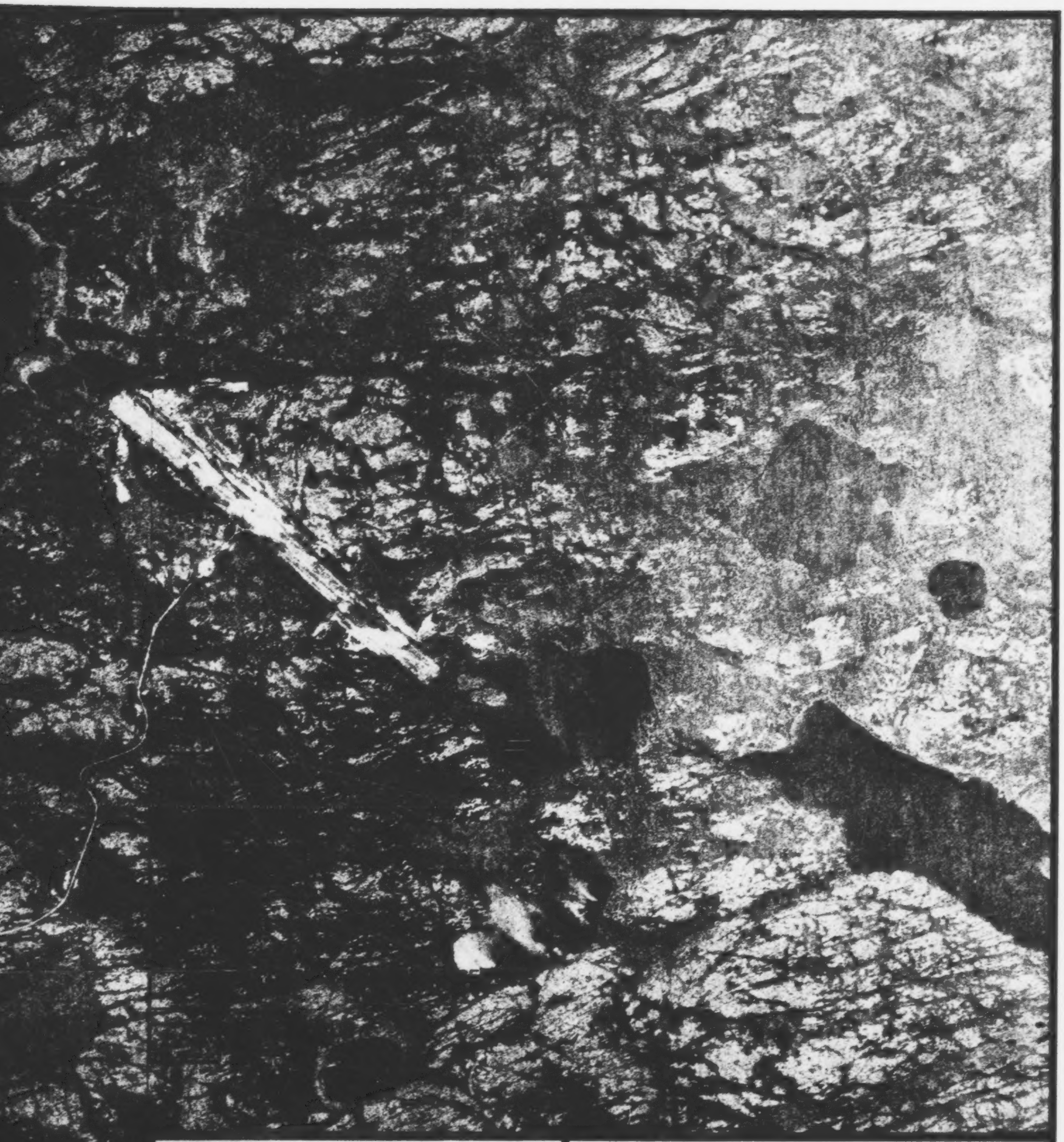

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VEGETATION COMMUNITIES

NATIONAL URANIUM TAILINGS PROGRAM

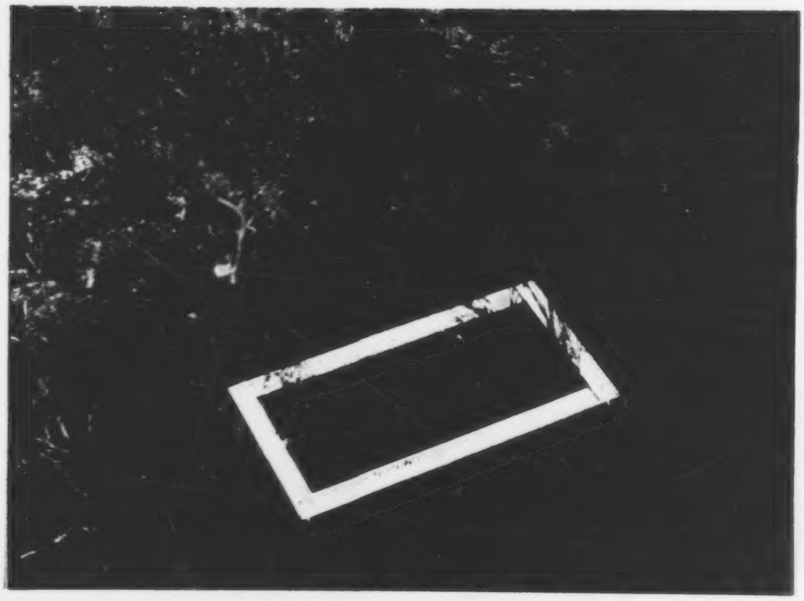
GUNNAR FIELD STUDY

SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE	DRAWN BY PMG	FIGURE NO. 1.11
DATE 30·01·86	APPROVED BY	

PHOTOGRAPH NO. 1.10

Foxtail barley (Hordeum jubatum) penetrates further into the dry, shifting tailings of Gunnar Main than does Salt grass (Pucinellia nutalliana). The Salt grass limit parallels the edge of the standing water on Gunnar Main.



PHOTOGRAPH NO. 1.11

Above ground plant biomass samples were clipped from within a 1/4 m^2 quadrant, shown here at a sampling point in the mud flat community (Juncus) on Gunnar Main. Ten quadrants were random placed in each community.

TABLE 1.9

RANGE OF RADIONUCLIDE LEVELS IN DOMINANT PLANT SPECIES FROM GUNNAR TAILINGS AND VICINITY, 1983 - 1985

Location	No. of Samples	U-238[1] ppm	Ra-226 Bq/g	Th-232 Bq/g	Th-230 Bq/g	Th-228 Bq/g	Pb-210 Bq/g
Gunnar Main[1]	11	< 0.2-91.9	0.05-2.4	< 0.01-0.38	< 0.01-0.84	< 0.01-0.38	0.16-2.1
Gunnar Central[1]	6	0.4-12.5	0.05-0.48	< 0.01	0.02-0.17	< 0.01-0.48	0.2-1.1
Langley Bay[1]	7	< 0.2-10.0	0.06-0.45	< 0.01	< 0.01-0.12	< 0.01-0.01	0.02-0.8
Frog Pond	3	< 0.2-1.2	0.06-0.12	< 0.01	< 0.01	< 0.01	0.27-0.74
Control 1	3	< 0.2-0.8	< 0.01-0.14	< 0.01	< 0.01-0.03	< 0.01-0.02	0.31-0.88
Control 2	3	< 0.2	< 0.01-0.03	< 0.01	< 0.01	< 0.01	0.32-0.34
Zemel Creek	1	0.6	0.06	< 0.01	< 0.01	< 0.01	0.48
Flooded Pit	2	< 0.2-1.4	0.11-0.14	< 0.01	< 0.01	< 0.01	0.24

---

[1] U-238 maxima on tailings are from 1983 samples (M. Apps, Northern Forest Research Station), minima from 1985 samples (this study); higher values in 1983 samples may be related to differences in sample preparation (1983 samples washed in the field; 1985 samples washed in the laboratory within four days of collection).

TABLE 1.10

RANGE OF RADIONUCLIDE LEVELS IN ROOT ZONE SOIL SAMPLES FROM GUNNAR TAILINGS, 1985

Location	No. of Samples	U-238 ppm	Ra-226 Bq/g	Th-232 Bq/g	Th-230 Bq/g	Th-228 Bq/g	Pb-210 Bq/g
Gunnar Main	2	83.5-95.8	7.9-9.9	0.10-0.16	5.6-10.7	0.26-0.32	7.2-8.8
Gunnar Central	1	41.1	4.6	0.04	3.2	0.30	5.8
Langley Bay	1	50.2	14.0	0.22	6.4	0.25	11.8
Frog Pond	1	64.4	34.0	0.22	14.0	0.74	10.0

1.6.6 Waste Rock

The majority of the waste rock produced during the operation of the Gunnar Mine was stored in 2 interconnecting piles east of the open pit, covering an area of approximately 10 ha. These piles form one of the dominant features of the landscape at the site (see Photograph No. 1.1). It is also reported that additional waste rock was used for general site grading and roadway construction. The waste rock piles are relatively barren areas with very little vegetation cover. It is reported that the piles are composed primarily of the stripping from the open pit and the waste from the open pit operation. The volume of stripping was estimated at 270,000 m^3 and was thought to have been spread underneath the present waste rock piles. The majority of the waste rock placed in the piles was from the open pit operation and is therefore expected to be relatively coarse in relation to the waste from the underground operations, which was primarily stored back underground.

Because the waste rock piles constitute a very significant component of the abandoned Gunnar Mine, a determination of the impact of the waste rock on the local environment was requested. The characteristics of the waste rock pile which were to be determined as part of the Gunnar Field Study, were set out in detail in the request for proposal. Generally, however, the characterization consists of a number of diverse measurements involving all of the technical disciplines utilized on the project. Some of the individual characteristics are discussed elsewhere in this report and appendices, but for convenience, all information relating to the waste rock was compiled into one volume (Volume 8, Appendix 7).

Volume

The volume in the surface waste rock piles was determined using the contours prepared from the 1976 photography. The calculations assumed that the bottom of the pile was a planar surface which coincided with the point where the edge of the pile intersected ground surface. The volume calculated was

2,710,700 m^3, which would include both waste rock and stripping. The volume of waste rock used for other purposes could not be quantified but is estimated to be less than 100,000 m^3.

Gamma Survey

The gamma emission survey was conducted using the hand-held, multiple range Berthold "Ratio/F" gamma dose-rate meter in June 1985. Readings were taken at heights of 0.1 and 0.2 m above the surface at 73 locations. Survey control for the readings was achieved by a transit and stadia method.

The average readings on the waste rock pile were approximately 150 uR/hr regardless of height. Only 10 percent of the readings from the 73 locations were greater than 1 mR/hr.

Physical and Chemical Characteristics

A total of 11 surface samples were recovered for physical and chemical laboratory testing. Only material smaller than 200 mm was sampled.

The combined gradation of 9 of the samples was 8 percent cobble sizes, 86 percent gravel sizes and 6 percent fines. The laboratory unit weight values of 1459 to 1584 kg/m^3 are thought to slightly underestimate the field conditions. The grading and density tests, however, do indicate a relatively high porosity in the pile. The petrographic examination found only minimal evidence of weathering.

A chemical analysis was performed on the waste rock material and radionuclide testing was performed on both samples of the rock and the dust. The results of these tests are included in Appendix 7, but of significance, is the fact that the levels of radionuclides and sulphates in the dust were approximately one order of magnitude higher than in the waste rock. However, because of radionuclide secular equilibrium, the dust fines are not believed to be windblown fines from tailings.

Radon Exhalation

One large mat (approximately 3 m by 3 m) was deployed on the northern edge of the waste rock pile in April 1985. Five cups were placed under the mat, one at the center, 2 at a distance of 0.45 m from the center on opposite sides of the center cup, and 2 at a distance of 0.9 m from the center on opposite sides of the center cup and on a line perpendicular to the axis formed by the other cups. This pattern of deployment was selected to assess the mat seal at the edges since it was thought that sealing would be more difficult on the waste rock pile due to the greater surface porosity.

The mat data for the 5 samples under the large mat on the waste rock pile are summarized in the appendix. No determination of flux rates can be made since cans were not installed on the surface. However, the data illustrate several features of the waste rock:

- The values are all within a value of 2. While standard deviations for the data are in the order of 10 percent (derived from counting statistics), the low range of values illustrates that few problems were experienced with the mat technique providing a representative level.
- Generally, the radon levels are significantly lower than those on the main tailings, 200 to 400 p Ci/l versus 20,000 to 40,000 p Ci/l on the main tailings. This is not unexpected, since the mineralization would be anticipated to be much lower.

Flow and Composition of Groundwater

The volume of water flowing from the edges of the pile could not be quantitatively measured due to the diffuse nature of the seepage faces. Samples of the seepage were recovered in June and August 1985. A complete chemical and radionuclide analysis was performed on the June sample and a partial analysis was performed on the August sample. Data collected earlier (1981) by SRC had indicated 2 seepage sources, one on the south side of the Waste Rock and one in the indentation of the Waste Rock Pile on the east side. In 1985, the east side seepage source was the only evident seepage and flows were lower than observed by SRC in 1981. These data suggest that seepage quantities vary both seasonally and from year to year, depending upon precipitation events. The levels of radionuclides and trace elements are also observed to vary considerably, with lead-210 being the most abundant radionuclide in the SEC study and Ra-226 being the most abundant in the 1985 sampling conducted as part of this study. Although the levels of Ra-226 observed in 1985, at close to 1 Bq/l, exceed Saskatchewan drinking water criteria, the fact that the seepage flows of between 1 to 5 l/s are low in comparison to the dilution in the receving waters of Lake Athabasca suggests that any ecological effects would be very localized if they existed at all.

Soil Surrounding the Waste Rock Pile

A total of 5 test holes were drilled in the area surrounding the waste rock pile in June 1985. The holes were hand-augered to a depth of 1.0 m and a sample was recovered from that depth. The profile consisted of 0 to 300 mm of topsoil over silty, varved clay. The properties of the clay were similar to clays underlying the tailings piles.

Chemical and radionuclide results were performed on soil samples from all 5 holes. The soils around the edge of the Waste Rock Pile consisted of a varved, silty clay that had been deformed to some degree by the weight of the nearby Waste Rock. In some areas, there was noticeable iron staining on the summer varves. The chemistry of these soils at Test Hole Nos. WR3 and WR4 and WR5 showed no evidence of significant movement of radionuclides out of the Waste Rock area. Slightly elevated levels of uranium were noted at Piezometer No. 2 in both the porewater and solids, suggesting some groundwater movement through silty lenses toward Lake Athabasca.

Vegetation

Harms and Fraser (1982) list the plant species found in the xeric shrub community on Gunnar mine wastes, along with frequency-abundance estimates based on interplant distance. Shrub abundance categories, according to Harms and Fraser, range from 'fairly frequent' (interplant distance approximately 5 m, e.g. Salix sp.) through 'locally frequent' (e.g. Rubus sp.) to 'occasional' (interplant distance approximately 10 m, e.g. Populus sp., Betula sp.). Fairly frequent herbaceous plants include grasses (e.g. Poa sp., Calamagrostis canadensis, Pucinellia nuttalliana, Hordeum jubatum), fireweed (Epilobium angustifolium) and bearberry (Arctostaphylos uva-ursi). The community has not changed greatly since the 1982 survey, although poplar shrubs were at least locally frequent based on the 1985 survey.

The waste rock community is the least productive of any described in the Gunnar area. The peak (August) biomass estimated from the 1985 survey was 18.66±21.37 gm dry weight/m^2.

1.6.7 Eating Habits of Local Population

Wild berries, including blueberries, cranberries, gooseberries and raspberries are consumed by Uranium City residents; however, picking is centered on Miliken Lake rather than the Gunnar site, and these species do not grow on Gunnar tailings. Cultivated vegetables, particularly potatoes, are grown for consumption in Uranium City, but are not likely affected by radionuclide transport from Gunnar.

Terrestrial wildlife in the Gunnar area of potential importance in human diets includes moose, caribou, rabbits, squirrels, grouse and ptarmigan. Fur-bearing small game such as coyote, red fox, lynx, marten, mink, otter and weasel are taken by a local trapper but are not eaten. Other small game are sufficiently common in the Uranium City area but few hunters would travel as far as Gunnar to obtain them. Moose hunters may travel this far, but there are no moose-kill records from Gunnar. Caribou are infrequently sited on the Crackington Peninsula, the last sitings dated from the winter of 1979/80.

Fish were commercially harvested in the vicinity of the Gunnar site throughout the 1960's and 1970's; a fish processing plant at Gunnar ceased operation in 1980. Catch statistics indicate that whitefish, lake trout and suckers were the main species harvested. Sport fishing continues in the area, for trout and pike in the vicinity of Langley Bay. The sport fishery harvest is unknown, but represents a potential significant human export pathway.

Statistics on eating habits of Uranium City residents, from Gillis (1975) prior to the Beaverlodge mine closure, indicate that wild meat was consumed on average 0.8 times/week, fish 1.0 times/week, vegetables 10.3 times/week and fruit 10.9 times/week. Wild meat and fish consumption may increase after Beaverlodge decommissioning, with reduced access to commercial food supplies.

1.6.8 Permafrost

During the initial drilling program in December 1984, frozen tailings were encountered at depths of 3.6 to 4.9 m in Test Hole No. N2A on Gunnar Main. The frozen tailings at this depth could not reasonably be attributed to seasonal frost penetration, and appeared to be relict frost from conditions of deposition or permanently frozen tailings resulting from surface heat loss. The Gunnar Mine is located in the discontinuous permafrost zone, as are all Northern Saskatchewan uranium tailings. It was subsequently decided by the Scientific Authority that field measurements, in addition to those presented in the original terms of reference, would be of benefit to determine the extent of the frozen tailings, with an eventual objective of providing a better understanding of the role of frost in the behaviour of tailings in northern environments.

The Gunnar Main Tailings area had an overall relief of approximately 10 m. The topographic high was located in the south portion of the tailings basin at the old spigot location, while the topographic lows were situated along the north and easterly portion of the basin. Surface water was ponded in some of the topographic lows (see Photograph Nos. 1.12 and 1.13). An interesting feature of the lower topography of the Gunnar Main Tailings was the presence of a number of ellipsoid-shaped elevated mounds (Photograph No. 1.12). These mounds extended approximately 1.0 m above the surrounding terrain and were several meters across. Test Hole No. N2A, which encountered frost at depth, was located on one of these mounds and it therefore appeared likely that the mounds were related to permanently frozen ground.

One theory proposed for the origin of these mounds was that they were similar to peat mounds or palsas which form in peatlands in the north. One consistent feature of their occurrence on the Gunnar project appeared to be that they formed adjacent to standing water in low-lying areas of the tailings where the water table was near ground surface. A readily available source of water seemed to be necessary for their formation. This representation was used to provide direction for the investigative program which followed.

The additional field measurements authorized by the Scientific Authority consisted of the following:

1) Additional drilling to identify areas of permanently frozen tailings within or adjacent to the mounds.

2) An electromagnetic survey to attempt to determine areas of permanently frozen tailings by means of electrical conductance techniques.

PHOTOGRAPH NO. 1.12

Lower area of Gunnar Main showing "frost heaves" adjacent to the ponded water (August 1985).

PHOTOGRAPH NO. 1.13

Installation at GM2 on Gunnar Main with ponded water in background. The monitor wells on the left are in frozen ground, while those on the right are not (August 1985).

3) Installation of thermistor strings to measure ground temperatures at selected locations during the summer of 1985.

4) Snow depth measurements in the winter of 1985.

The area selected for the EM survey was on Gunnar Main, and was large enough to encompass a number of the mounds and also areas not suspected of having permafrost. This area is shown on Figure No. 1.12 and was used as the basis for all supplementary work relating to the permafrost.

The actual program of fieldwork consisted of the following:

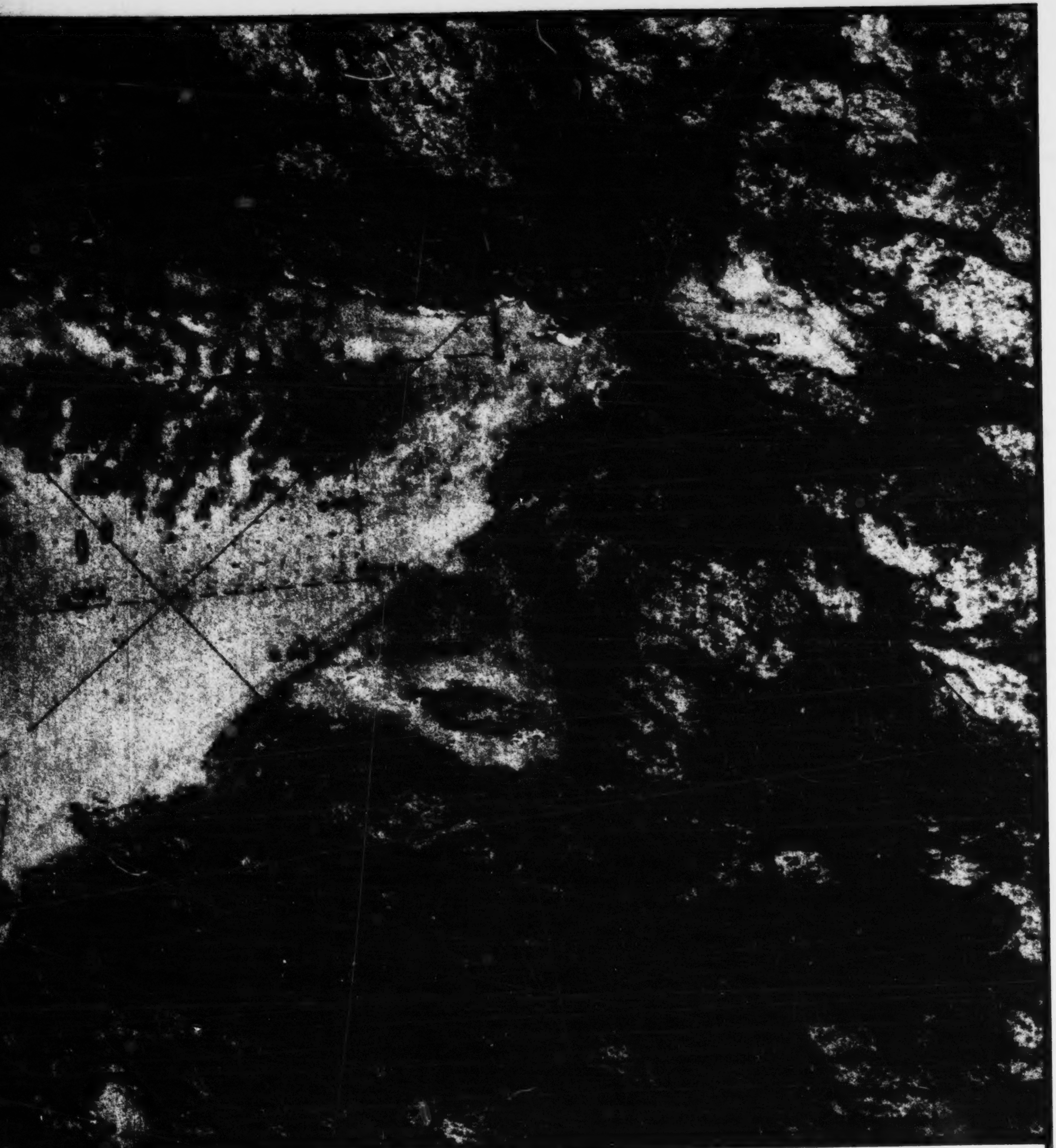
1. Electromagnetic Survey

   The grid points for the EM survey are shown on Figure No. 1.12. The survey was conducted in March 1985 using EM 31 and EM 34 equipment. It was originally intended to redo the survey in the summer, but when it was observed that the results were going to be inconclusive, this survey was abandoned. The complete EM survey results are included as Section 10.5, Volume 10, Appendix 9. The equipment in use is shown on Photograph No. 1.14.

2. Snow Depth Measurements

   Snow depth measurements were made during the March campaign at the same grid points as the EM survey. The snow depth measurements are presented in Table 10.3, Volume 10, Appendix 9, but generally varied up to 1.0 m in the hollows with the top of the mounds bare (see Photograph No. 1.15).

GM 13
GM 12
LEFT
100
120
140
160
180
200
GM 11



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P. E. Pehme MSc.

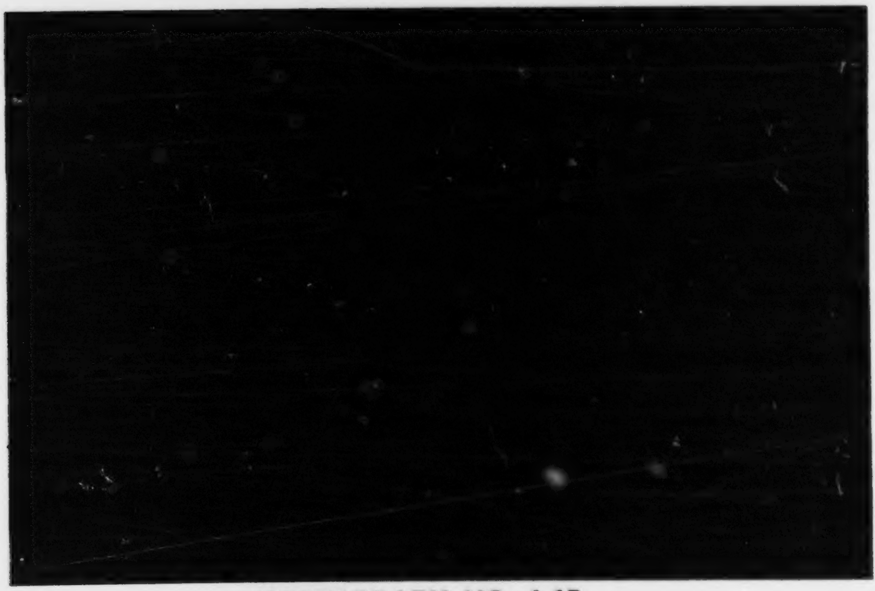
EM SURVEY LOCATIONS

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1: 5000	DRAWN BY W.T.	FIGURE NO. 1.12
DATE DEC. '85	APPROVED BY	

PHOTOGRAPH NO. 1.14

Gunnar Main EM Survey.
March 1985



PHOTOGRAPH NO. 1.15

Gunnar Main showing the EM baseline. Note the wind erosion of the tailings.

3. Thermistor Installations

A total of 9 thermistor strings were installed in the study area with 2 of them, GM6 and N2, being installed through mounds. The thermistor strings were installed using one of 3 procedures, namely: 1) taping the string to the outside of a piezometer and installing the unit in a recently drilled hole; 2) hanging the string down a hole and backfilling with tailings; and, 3) hanging the string down an existing piezometer. The location of the thermistors is shown on Figure No. 1.12 and further information is provided on Table 1.11. The number of installations was limited due to equipment problems and time constraints. The thermistors were read at 2 week to 1 month intervals from March to August 1985. A complete listing of the results is presented as Table 10.2, Volume 10, Appendix 9 with graphical presentations as Figure Nos. 10.4 to 10.12 in the same volume. The graphical presentation for Test Hole No. GM6A is included as an example in this volume as Figure No. 1.13. Note that the ground is indicated as premanently frozen below a depth of 2 m.

4. Drill Cutting Observations

A total of 13 test hole logs are included in Volume 10, Appendix 9. These represent the test holes with thermistors, those with direct ground temperature measurements and those in which ground ice was observed. The log for Test Hole No. GM6A is included in this volume (Figure 1.15) as an example of ground ice observations and to provide references for the thermistor readings.

The additional test drilling confirmed the presence of permanently frozen tailings within the elevated mounds on Gunnar Main (Test Hole Nos. N2A, GM2A and GM6A). It is also significant, however, that the drilling did not encounter any permanently frozen tailings in the areas immediately adjacent to the mounds. Generally, the thermistor readings confirmed the visual observations, although in some cases (Test Hole No. N2F), the thermistor was not installed deep enough to reach the permanently frozen ground. It would seem reasonable to conclude, therefore, that the elevated mounds found on Gunnar Main are the result of permafrost.

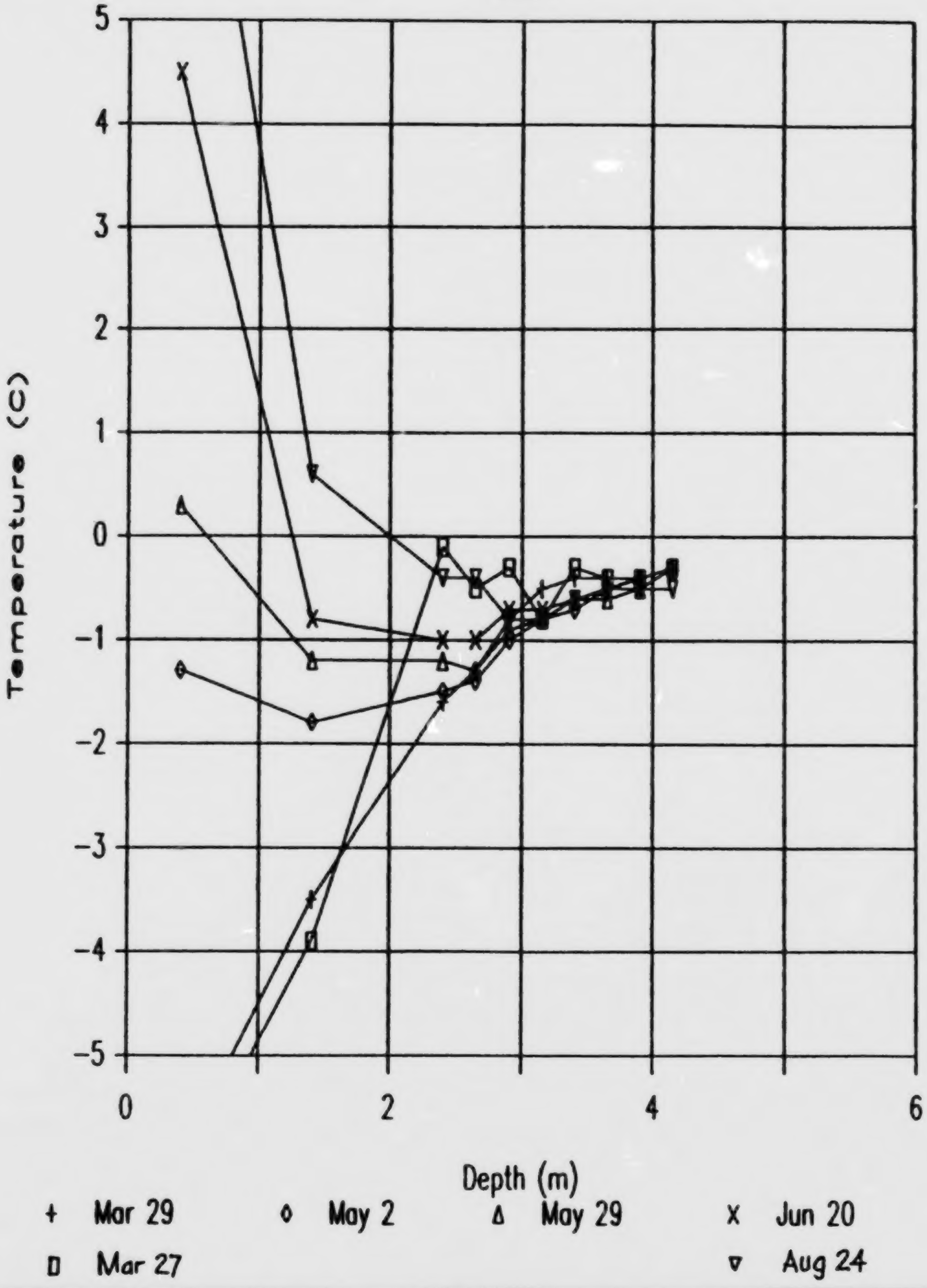
TABLE 1.11

TEST HOLE AND THERMISTOR INFORMATION

Location Information	Northing (m)	Easting (m)	Ground Elevation (m)	Thermistor String Length (m)	Test Depth Drilled (m)	Depth Below Ground Surface Lowest Thermistor (m)	Comments
N1C	1232	3883	106.64	9.5	11.89	8.92	Installed inside the monitor well.
N1F	1227	3875	106.64	9.5	4.9	4.00	String taped to outside of monitor well.
N2F	1342	3701	101.81	8.75	12.2	3.44	String taped to outside of monitor well.
N6A	1634	3905	99.99	9.5	11.25	8.8	Installed inside the monitor well.
GM2A	1425	3928	104.10	8.75	8.4	5.27	Installed in test hole and backfilled with tailings.
GM3A	1214	3631	101.98	9.5	19.8	4.4	Installed in test hole and backfilled with tailings.
GM4A	1632	3315	100.92	9.5	4.8	4.2	Installed in test hole and backfilled with tailings.
GM6A	1543	3863	101.68	8.75	11.0	4.15	String taped to outside of monitor well.
GM9B	1658	4107	101.44	8.75	4.10	4.83	String taped to outside of monitor well.

TEMPERATURE PROFILE

GM6A



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GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

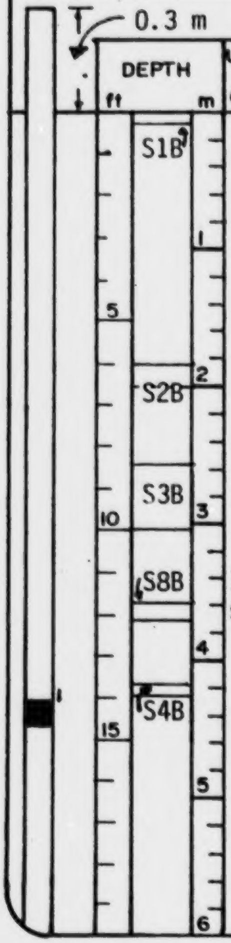
FIGURE NO. 1.13

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID:	Gunnar Main	TH - TEST HOLE / TP - TEST PIT:	TH
LOCATION ID:	GM6A On Knoll	DRILLER / EXCAVATOR:	Wiseman
SITE COORDINATES:		COMPLETION DATE:	85/03/14
N	1543	TEST HOLE DIAMETER (m):	0.056
E	3863	TOTAL DEPTH (m)	11.0
GROUND ELEVATION (m)	101.68		
Thermistor OWNER	NUTP	FILTER PACK LENGTH (m)	
INSTALLER	R. Boivin	FORMATION OF COMPLETION:	
INSTALLATION DATE	85/03/14	Lowest Therm. DEPTH (m)	4.15
CASING ELEV. (m)	101.98 *	OPEN/SCREEN DEPTH (m)	4.15
CASING LENGTH (m)	4.45	OPEN / SCREEN LENGTH (m)	0.127
CASING DIAMETER (m)	0.035	OPEN / SCREEN AREA (m^2)	0.0203

LITHOLOGICAL SUMMARY



DEPTH	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	SM Vx	15.2				SAND - some frozen, some dry, visible ice crystals in frozen portion, poorly graded, fine, reddish brown and grey brown, reddish brown portions appear to be frozen, grey brown silty.
S2B	SM					Attempted tube at 1.8 m, no recovery.
S3B	SM	22.6				SAND - silty, frozen, very moist below frost, visible ice excess, crystals.
S8B	ICE & soil inclusions					3.6 m - ICE with soil inclusions.
S4B	ML	32.6				Less ice at 4.2 m again. SILT - saturated, low to non-plastic, reddish brown, sandy. Frost ends at 4.3 m. Nothing in core barrel at 4.6 m, nothing in core barrel at 6.0 m.

* Elevation calculated from ground elevation plus pipe.

FIGURE NO. 1.14(a)

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM6A

LITHOLOGICAL SUMMARY (CONTINUED)

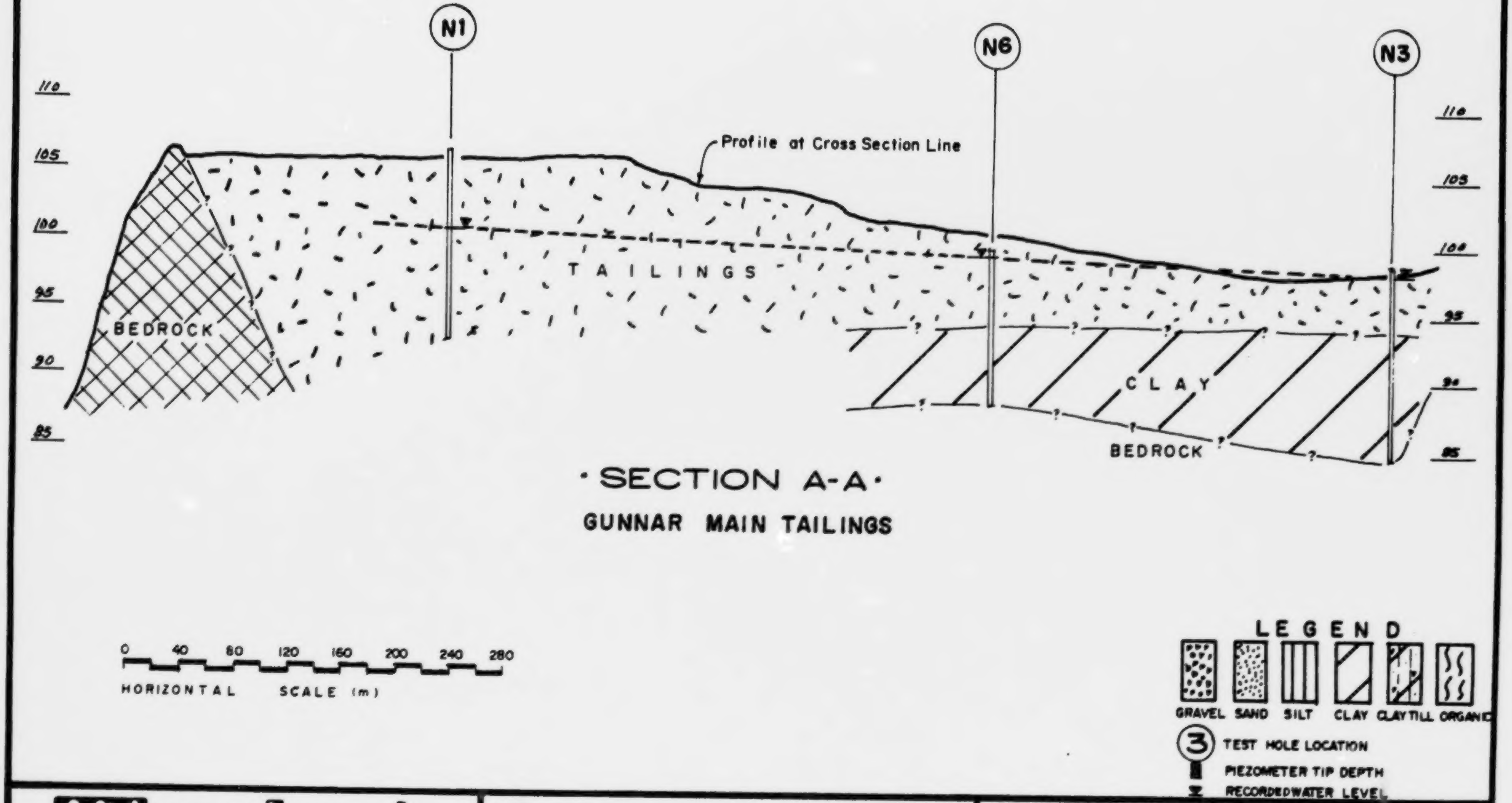
DEPTH ft.		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
		7						
25	S5B	8	ML	33.5				SILT - saturated, low to non-plastic, reddish brown, sandy, greenish brown layers, trace roots, silty.
30		9						Nothing in core barrel at 9.1 m.
		10						
35	S6B		CI					Minimal recovery at 10.7 m. CLAY - saturated, medium plastic, soft, light grey.
		11						Casing refusal at 11.0 m.
40		12						8.75 m string thermistor installed, lowest at 4.15 m. Could not get pipe any lower even after cleaning out hole twice.
		13						Thermistor installed on outside of pipe.
45		14						
		15						

FIGURE NO. 1.14(b)

The electromagnetic (EM) survey was inconclusive in determining areas of permafrost because of the relatively high conductivity of the saturated tailings. It was originally intended that the combined results of the additional field measurements could be used to generate some fundamental understanding of frost in tailings in the discontinuous permafrost zone of Northern Saskatchewan. Largely as a result of the ineffectiveness of the EM survey, this was not possible, however.

Some insight into the factors which might contribute to the formation of the permafrost zones in the tailings can be found by looking at some of the other data generated by The Gunnar Field Study. The surface mounds were primarily found in the topographic lows of the Gunnar Main Tailings. Three factors which are also common to the topographic lows are finer, siltier textured tailings, tailings with a lower permeability, and a high water table. All 3 of these factors are conducive to frost action. Figure No. 1.15 is a typical cross-section through Gunnar Main showing the position of the water table in the topographic lows.

The occurrence of permanently frozen ground within the tailings at some locations suggests that this condition might be cultivated as a means of reducing release rates. The data collected as part of The Gunnar Field Study, however, were not detailed enough to provide the specific combinations of tailings type, water table position, snow cover, climate and exposure which would be necessary to develop this condition.


N1
N6
N3
Profile at Cross Section Line
110
105
100
95
90
85
BEDROCK
TAILINGS
CLAY
BEDROCK
0
40
80
120
160
200
240
280
HORIZONTAL SCALE (m)
LEGEND
GRAVEL
SAND
SILT
CLAY
CLAYTILL
ORGANIC
3
TEST HOLE LOCATION
PIEZOMETER TIP DEPTH
RECORDEDWATER LEVEL

·SECTION A-A·

GUNNAR MAIN TAILINGS

Geotechnical Consultants Ltd.

INTERPRETED SUBSOIL STRATIGRAPHY

NOTE: THE INFERRED SOIL STRATIFICATION HAS BEEN INTERPRETED FROM DATA OBTAINED AT TEST HOLE LOCATIONS ONLY. THE INFERRED CONTACTS SHOWN ARE BASED ON GEOLOGICAL EVIDENCE AND MAY VARY FROM THOSE SHOWN BETWEEN TEST HOLES.

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN
FIGURE NO. 1.15

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Volume

2

CONTRACT REPORT NUMBER: OSQ 84-00195
VOLUME 2
APPENDIX 1

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
CONTRACT NO. 55SQ.2341-4-1674X

Volume 2 (Appendix 1)

Chemical Test Procedures and QA/QC Program

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THE GUNNAR FIELD STUDY

The Gunnar Field Study consists of 10 volumes, each published separately. Volumes 2 to 10 are supplements to Volume 1, written as Appendices 1 to 9.

The volumes are:

- Volume 1 - Summary Report
- Volume 2 - Test Procedures and QA/QC Program (Appendix 1)
- Volume 3 - Atmospheric Studies (Appendix 2)
- Volume 4 - Tailings Solids and Surrounding Soils (Appendix 3)
- Volume 5 - Groundwater (Appendix 4)
- Volume 6 - Surface Water (Appendix 5)
- Volume 7 - Biology (Appendix 7)
- Volume 8 - Waste Rock (Appendix 7)
- Volume 10 - Permafrost (Appendix 9)

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VOLUME 2, APPENDIX 1: CHEMICAL TEST PROCEDURE AND QA/QC PROGRAM

2.0 INTRODUCTION

Chemical analyses were carried out on a wide range of environmental materials including tailings solids, the porewater in contact with these solids, the surface waters draining the tailings, the porewater in contact with the geological materials underlying the tailings, vegetation growing on and in the immediate proximity of the tailings, dust eroded by wind from the tailings surface, and radon degassed from the tailings. All of these different environmental compartments comprising a wide range of environmental matrices were analyzed for major and trace stable elements and radionuclides of the U-238 and Th-232 decay series.

In this appendix, the laboratory facilities, analytical methods and internal quality assurance program of the different laboratories are described. External quality control (blind replicates, duplicate samples submitted to difference laboratories) are described in the appropriate section in other Appendices. Analytical results of the laboratory QC program are also given in this Appendix. Where standard test procedures such as in the American Standard for Test Materials (ASTM) were used, the procedures were not detailed but merely referenced.

The laboratories described in this appendix (see Table 2.1a) are Beak Analytical Services, Barringer Magenta Ltd., and Saskatchewan Research Council (SRC) for major cations and anions; and Saskatchewan Research Council (SRC) Laboratories, Monenco Analytical Laboratories and Chemex Laboratories for radiochemical analysis. Beak Analytical Services was the primary laboratory for major elements for all environments (surface water, porewater, tailings solids, vegetation, atmospheric dust). SRC was the main check laboratory for interlaboratory comparison for these environments, except that Barringer Magenta was used as a check laboratory for surface water samples. SRC was the primary laboratory for analysis of radionuclides in porewater, tailings solids and atmospheric dust. Monenco Analytical Laboratories was the primary laboratory for vegetation and surface water measurements. Monenco was used as the check laboratory for porewater, tailings solids and atmospheric dust while SRC and Chemex were used as check laboratories for the surface water program. AECL Pinwawa, Manitoba was used as the check laboratory for radionuclides in vegetation.

General Comment of Quality Assurance Program

Definition

Quality assurance comprises all those planned and systematic actions necessary to provide adequate confidence in the results of a monitoring program. Quality control comprises those quality assurance actions that provide a means to control and measure the characteristics of measurement equipment and processes to established requirements.

Quality assurance is the total program for assuring the reliability of monitoring data.

Quality control is the routine application of procedures for controlling the measurement process. Quality assurance includes aware personnel, proper instrumentation, analytical methods, quality control, record keeping and management support.

Analytical Repeatability

Analytical repeatability (also called precision), is the ability of the laboratory to reproduce the same value for the same sample sub-divided into independent test portions. Repeatability is generally limited by one of the following factors, in order of increasing significance.

- electronic (instrument) noise observed under extreme range expansion,
- inability to observe small changes in reading because of insufficient range expansion,
- analytical noise, e.g., non-reproducible colour development or noisy reagent background, independent of sample preparation procedures,
- sample preparation noise, e.g., poor repeatability after sample digestion,
- sample non-homogeneity,
- poor sampling or sample handling and preservation.

With respect to terminology, the following ISO/REMCO definitions have been adopted:

- **Analytical repeatability** involves the laboratory subdividing the same sample into independent test portions and analyzing it as two samples
- **Interlaboratory programs** where the different laboratories analyze the same sample, measure **reproducibility** and can be used to monitor the relative accuracy of the methods.

Quality control and performance evaluation attempt to minimize and quantify the scatter of data resulting from the analytical measurements. The following data base is useful:

- results of duplicate analysis of samples split at the laboratory for use in assessing in-lab precision,

- results of duplicate samples submitted "blind" from the field (e.g., a sample split in two in the field) for assessing the additional effect of field activities and sample type, or perishability, on precision,

- results of duplicate samples where one is analysed "blind" by the primary laboratory, and the other forwarded to a second laboratory for analyses during the same time frame.

Detection limit and precision statements are advisory in nature. Field and/or time variability usually do not permit application of these concepts to assist the data user in interpreting his results unless in fact analytical effects are limiting.

The stated values (Table 2.1), for non radionuclide parameters, are achievable provided that major ions do not cause analytical interferences. Examples of interferences include the following. If one species dominates, colorimetric or spectral interference may result during cation-anion analysis or an energy interference during radionuclide analysis. Spectral interferences occur when the interfering ion has a peak on the spectrum at the same or overlapping location as the primary ion of interest. Suitable dilutions for such interferences are necessary and may improve the detection limit. But dilution may also remove the ion of interest from its detectable range. Dilutions are also used to check for linearity.

TABLE 2.1: ANALYTICAL METHODOLOGY SURVEY OPERATING CHARACTERISTICS OF METHODS

TYPE OF SAMPLE: Water

Parameter	Units of Measurement	Routine Analytical Operating Range Upper	Lower High	Lower Low	Best Method Lowest Reported	Method	Sample Preparation Laboratory Nomenclature	Bias (versus true value)	Literature Reference
pH	units	0-14	0.1	0.05	0.01	Meter	Probe*	-	APHA 423, 1983
Acidity ($CaCO_3$)	mg/L	500	1	0.5	0.5	Meter	Titration*	-	APHA 402, 1983
Alkalinity ($CaCO_3$)	mg/L	500	1	0.5	0.5	Meter	Titration*	-	APHA 403, 1983
Conductivity	umhos/cm	wide	1	0.1	0.1	Meter	Probe*	-	APHA 205, 1983
Total Dissolved Solids	mg/L	wide	1	0.5	0.5	105°C	Filter GFC 1.2 u	high/low	APHA 209C, 1983
DOC	mg/L	50	1	0.5	0.5	Analyser	Filter GFC 1.2 u	high/low	BOM 1
DIC	mg/L	50	1	0.5	0.5	Analyser	Filter GFC 1.2 u	high/low	BOM 1
Kjeldahl-N	mg/L	2	0.1	0.02	0.01	Nessler	Digestion HgO/Distillation	high	APHA 421 Modified, 1983
Major Anions	mg/L								
Bromide		200	1	0.1	0.05	IC	Filtered, DIONEX	-	DOM
Chloride		35	0.5	0.1	0.1	IC	Filtered, DIONEX	-	DOM
Fluoride		20	0.1	0.01	0.003	IC	Filtered, DIONEX	-	DOM
O-Phosphate		300	0.2	0.05	0.01	IC/$SnCl_2$	Dissolved, reactive P	low	DOM, APHA 424, 1983
Sulphate		200	1	0.2	0.05	IC	Filtered, DIONEX	-	DOM
Nitrate		200	0.1	0.01	0.01	IC/Brucine	Filtered, DIONEX	low/high	DOM, APHA 213C, 1971
Nitrite		100	0.2	0.01	0.001	IC	Filtered, DIONEX	-	DOM
Major Cations	mg/L								
Magnesium		400	0.1	0.01	0.005	DCP	Field Filtered, Acidified	-	BOM2
Calcium		400	0.2	0.05	0.02	DCP	Field Filtered, Acidified	Low	BOM2
Iron		200	0.02	0.01	0.005	DCP	Field Filtered, Acidified	-	BOM2
Manganese		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Silica		100	0.1	0.05	0.02	DCP	Field Filtered, Acidified	-	BOM2
Aluminum		100	0.1	0.01	0.05	DCP	Field Filtered, Acidified	-	BOM2
Sodium		200	0.2	0.1	0.05	DCP	Field Filtered, Acidified	-	BOM2
Potassium		100	0.1	0.02	0.01	DCP	Field Filtered, Acidified	-	BOM2
Trace Cations	mg/L								
Strontium		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Lead		100	0.02	0.01	0.005	DCP	Field Filtered, Acidified	high	BOM2
Cobalt		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Nickel		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Zinc		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Chromium		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Copper		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Cadmium		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	high	BOM2
Barium		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Vanadium		2	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Titanium		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Arsenic	ug/L	10	1	0.5	0.2	FAA	Field Filtered, Acidified	-	Anal. Chim. Acta 93 p. 61, 1977
Selenium	ug/L	10	1	0.5	0.2	FAA	Field Filtered, Acidified	-	Anal. Chim. Acta 93 p. 61, 1977
Molybdenum		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM 2
Beryllium		2	0.01	0.005	0.002	DCP	Field Filtered, Acifified	-	BOM 2

BOM1 - Beckman Operations Manual (TOC Analyser)
APHA - Standard Methods for the Examination of Water and Wastewater, 15th Ed.
* Samples as received, unfiltered in laboratory

BOM2 - Beckman Operations Manual (DCP)
DOM - Dionex Operations Manual

TABLE 2.1(a) COLLECTION OF FIELD SAMPLES * AND LABORATORY MEASUREMENTS

Environment	Sampling Responsibility	Laboratory Involvement		
		Parameters	Primary Laboratory	Check Laboratory
Tailings Solids	BBT	Major Radionuclide	Beak ** SRC	Barringer
Tailings Porewater	BBT/Beak	Major Radionuclide	Beak SRC	Barringer
Surface Water	Beak	Major Radionuclide	Beak SRC	Barringer Monenco Chemex
Biological and Vegetation Tissues	Beak	Major Radionuclide Bacteria	Beak SRC Waterloo	Barringer Monenco
Radon Monitoring	Concord	-	Terradex	-
Gamma Measurements	Concord	-	Princess Margaret Hospital	-

** SRC - Saskatchewan Research Council.

* Laboratories responsible for field sampling were also responsible for all field measurements in their area of responsibility.

Lower detection limits and lower method sensitivity (good precision and accuracy) require additional test runs on undiluted and/or spiked samples or may be enhanced by extraction/separation/concentration techniques. In some cases, the swamping effects cannot be overcome by other specific procedures available to normal laboratories. In some cases, special methods may allow the laboratory to go below the best stated detection limits given in Table 2.1.

If the user requires data with better precision or lower detection limits, the user should consult the laboratory to see whether the analytical system can be adapted to his needs.

Analytical Accuracy

Accuracy measures the bias which has been found, relative to some reference or established true value. If precision is sufficiently poor, bias will be difficult to detect; however, its influence on averaged data will still be real.

Analytical accuracy is determined by processing calibration and test reference materials at the same time that the routine samples are analysed. It has been found that standards used to produce calibration curves and reference samples must have similar matrices to ensure that the instrument responds similarly to the interferences from the matrix. Reference materials are used for certain parameters that normally need correction for bias.

Laboratory Assurance Programs

Experience has shown that quality assurance programs must monitor internal laboratory performance on a continuous basis to ensure accurate and repeatable data. The following routine procedures may be included in analytical studies.

- o Use certified reference materials.
- o Use reference solutions to check bias.
- o Use secondary standards prepared from CRM's to check bias.

- Process internal replicates.
- Process blind replicates.
- Carry out spiking to eliminate interferences and confirm recovery.
- Balance the anion and cation ratio (if applicable).
- Interlaboratory cross-checks. Several external checks are carried out each year by the different laboratories. This information is used to monitor accuracy of methods and any bias. This information is available if requested.

2.1 Beak Laboratories

Beak Analytical Services (Mississauga, Ontario) was the primary laboratory for analysis of non-radionuclide parameters for Gunnar of the following components:

- tailings solids,
- tailings porewater,
- surface water,
- atmospheric dust,
- biological tissues and vegetation.

2.1.1 Laboratory Methods of Analysis (Beak Laboratories)

With a few exceptions detailed below, the chemical analyses described in this section were performed upon liquid samples. For cases where solid samples were analyzed, the solid samples were dissolved into a liquid phase using an appropriate digestion procedure.

With the exception of the DCP metals scan and the IC methods for 7 anions (NO_3^-, NO_2^-, SO_4^{2-}, $PO_4^{3=}$, Cl^-, Br^-, F^-), the analytical methods used are well established, published methods whose development and application in similar aquatic and solids samples have been used for approximately a decade. The methods are described in detail in (i) APHA (1983: Standard Methods for the Examination of Water and Wastewater), (ii) Environment Canada (1979: Analytical Methods Manual), and (iii) Allen et al, (1974: Chemical Analysis of Ecological Materials").

Table 2.1 describes the operating characteristics of the methods. A summary of the methods is given below; an overview of the methods is given in Table 2.2. The majority of the cationic (metals and elemental) analyses were done on the DCP instrument except for mercury by cold vapour flameless AA and selected metals including arsenic and selenium by hydride evolution - flameless AA.

TABLE 2.2a SUMMARY OF TEST METHODS (BEAK LABS)

Tailings Solids

Total Digestion	o	Fusion of 0.25 g portion with lithium metaborate, dissolution in 5% nitric acid.
Water Leachate Metals	o	Leaching of 5 g portion with distilled deionized water until conductivity less than 50 umhos/cm.
Acid Leached Metals	o	Dilute nitric acid leach of residue after distilled deionized water leach.
DCP Analysis	o	Direct current plasma emission analysis of total digestion. For fractional analysis, water leach and dilute acid leach was used.
Sulphide	o	Total sulphur analysis of residue after dilute nitric acid leach or water leach, using a combustion sulphur analyzer.
Sulphate	o	Turbidimetric or ion chromatographic analysis of distilled water or nitric acid leach. IC is used where DOC interferes.
Carbonate	o	Back titration after acid addition to solids.
CEC	o	Ammonia analysis after displacing exchanged ammonia from the material with a stronger cation.

Pore Water

DCP Analysis	o	DCP analysis of a centrifuged acidified sample.
IC Scan	o	Dionex 10 ion chromatography with prefiltration.
Ammonia	o	Nesslerization after distillation.
Arsenic	o	Flameless hydride generation using sodium borohydride.
Selenium	o	Flameless hydride generation using sodium borohydride.
Reduced Sulphur	o	Turbidimetric sulphate analysis before and after oxidation of all reduced sulphur compounds to sulphate

TABLE 2.2 (Cont'd) SUMMARY OF TEST METHODS (BEAK LABS)

Surface Water	
DCP Analysis	o DCP Analysis of an acidified sample.
Arsenic	o Flameless hydride generation using sodium borohydride.
Selenium	o As above.
Boron	o Direct current plasma emission.
IC Scan	o Dionex 10 ion chromatography.
Suspended Solids	o Gravimetric after filtration (Whatman GF/C glass fiber) and desiccation at 105° C
Colour	o Direct comparision using Nessler tubes with Co-Pt Standard.
Turbidity	o Direct readout using a Hach 2100 turbidimeter.
Ammonia	o As above.
Kjeldahl N	o Potassium sulphate and mercuric oxide micro kjeldahl digestion followed by Nesslerization of ammonia.
O-Phosphate P	o Colourimetric reaction with stannous chloride and ammonium molybdate or ion chromatography.
Total Phosphate P	o Sulphuric acid and potassium persulphate digestion followed by stannous chloride and ammonium molybdate reaction.
TOC	o Beckman 915A total organic carbon analyzer.
TIC	o Beckman 915A total organic carbon analyzer (inorganic channel).

(i) Alkalinity/Acidity - Liquids

Alkalinity was measured by titration of a portion of the sample to pH 4.5 with standardized sulphuric acid and then to pH 4.2 under the laboratory atmosphere. Acidity was determined by titration to pH 8.3 with standardized sodium hydroxide. In both cases a Radiometer pH meter was used after calibration with pH 4 and 10 buffers. These end points are appropriate for aqueous samples such as those of tailings which contain 5-10 mg TIC/L or more.

For Gunnar samples, both acidity and alkalinity values are reported.

(ii) Anion Scan (PO_4^{3-}, NO_3^-, NO_2^-, Cl^-, $SO_{4-}{}^{2-}$, F^-, Br^-)

The anions were determined by ion chromatography on liquid samples using a Dionex model 10 system with the detection limits given in Table 2.1.

(iii) Carbonate - (Solids)

Carbonate was also determined indirectly using a titrimetric procedure. An accurately dispensed quantity of 0.01 N hydrochloric acid was added to a 15 g portion and the mixture was allowed to react for two hours with occasional stirring. During this process, carbonates were broken down and driven off as CO_2. The unreacted acid was then back-titrated with a standardized carbonate-free sodium hydroxide solution. The carbonate is then calculated from the amount of acid used up during the reaction. Due to the nature of the solids, difficulties were encountered during the analysis and no carbonates were detected (Allen et al, 1974; Section 23.9).

(iv) Cation Exchange Capacity - Solids

Cation exchange capacity was determined by washing a weighed portion of air-dried sample with a solution of ammonium acetate. The sample was then washed thoroughly with 57% ethanol and leached with a potassium chloride solution. The leachate was analyzed for ammonia by the automated phenate method. The cation exchange capacity is equal to the number of milliequivalent of ammonia leached from the ammonia acetate washed material. CEC was reported on a meq/100g basis. (Allen et al, 1974; Section 7.8).

(v) Loss on Ignition (LOI) - Solids

LOI was measured gravimetrically on a moisture free sample by ashing at 550° to a constant weight.

(vi) Metals

(a) Metal Scan for Liquids: Direct Current Plasma (DCP) Analyser

Ag, Al, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Na, K, Pb, Ni, Ti, Sr, U, Zn, Si and B were analyzed by DCP. The DCP is a Beckman Spectraspan V Direct Current Plasma Analyser with a Spectrajet III DC argon plasma excitation source. It has two ten element cassettes for simultaneous determination of metals: one cassette for cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, silver, and zinc; and one cassette for aluminum, barium, beryllium, calcium, magnesium, molybdenum, potassium, sodium, strontium, and vanadium on the other cassette. A single element cassette was used for sequential determination of other single elements such as boron, thorium, silicon and titanium. A DBC-33 dynamic background compensator, a microprocessor controlled RS-232C data interface, an auto sampler interface, and a printer are ancillary pieces of equipment.

Instrument operation is not described in generally available documentation (e.g., APHA, 1983: EC, 1979; OMOE, 1984). Reference is most readily made to the operational manuals, and accompanying literature.

(b) Selenium and Arsenic in Liquids: Atomic Absorption Spectrophotometer

A Perkin-Elmer Model 303 was used to measure selenium and arsenic by hydride generation using sodium borohydride. For selenium and arsenic interferences, the lower limits were enhanced by using high energy electrodeless discharge lamps. Occasionally, the known-addition technique was used to eliminate interferences. Known standards were used to construct a calibration curve.

(c) Mercury in Liquids

A Perkin Elmer 403 spectrophotometer was used to analyze mercury by cold vapour technique using stannous sulphate reductant with a hollow cathode lamp. Known standards were used to construct the calibration curve.

(d) Porewater Samples - Total Metals

The porewater samples were analyzed for metals by DCP with the detection limits given in Table 2.1 upon field-filtered, porewater samples.

(e) Surface Water Samples - Total Metals

Field acidified samples (HNO_3 preserved) were analyzed without further digestion by DCP after the addition of 1000 ppm lithium as a chloride salt.

Special Analytical Procedures for Solids

Tailings Solids - Leachable Portion of Solids

(a) Leachate Study No. 1

The tailings solids were analyzed for heavy metals after two separate sequential leaching procedures. The first involved the leaching of a 5 g aliquot of sample material with distilled, demineralized water until the conductivity was below 50 umhos/cm. The sample was then leached with 30 ml of 1M HCl - 4M HNO_3 at 90°C for 2 hours. After cooling and centrifuging, the supernatant was decanted and made up to 50 ml. The leachate in each case was analyzed for metals by DCP.

(b) Leachate Study #2, 3, 4

A 5g portion was leached with distilled, deionized water until the conductivity was below 50 umho/cm. The residue was dried and then a 0.25 g portion was fused with lithium metaborate.

Tailings Solids - Total Metals

The total heavy metals were determined by fusing a 0.25 g aliquot of dried, homogenized residue from the above leaching or original homogenized tailings material with lithium metaborate. The molten residue was dissolved in 5% nitric acid. Due to the dissolved solids content of the resultant solution, a minimum dilution factor of 20 was necessary. Cations were determined by DCP scans in liquid samples.

Tailings and Porewater Combined

A portion of wet material equivalent to 20 g dry tailings was weighed out. This wet material was mixed with a volume of water which, together with the moisture of the material was equivalent to 200 g of water. A portion of the wet ooze equivalent to 20 g dry weight was weighed out. This wet material was mixed with a volume of 192 mL of water which, together with the moisture of material was equivalent to 200 g of water. After agitation for two hours the suspension was settled, a portion was centrifuged and the supernatant was analysed by IC directly nd DCP after acidification with nitric acid.

A portion of the "ooze" was centrifuged and the supernatant was analysed by IC directly and DCP after acidification with nitric acid. The results are given in Table 2.2b.

(vii) Moisture Content - Solids

Moisture content was determined gravimetrically by drying to constant weight at 105°C.

(viii) Nutrients

(a) Nitrogen Species

Nitrate and nitrite were determined by ion chromatography using a Dionex Model 10 system with detection limits given in Table 2.1. Because sulphate often interfered with their determination at the low concentrations, colorimetric methods were also used at low levels.

TABLE 2.2b: RESULTS OF SPECIAL STUDY ON FROZEN TAILINGS AND OOZE

Parameter	Frozen Tailings	Ooze
IC Scan (mg/L)		
Fluoride	0.4	0.3
Chloride	10.5/11.2	16.9
Sulphate	1380/1440	1410/1420
pH	7.6	7.6
DCP Scan (mg/L)		
Beryllium	L 0.01	L 0.01
Molybdenum	0.14	0.14
Calcium	530	540
Vanadium	0.04	0.04
Aluminum	1.12	1.20
Magnesium	37	45
Barium	0.03	0.03
Potassium	1.05	1.24
Strontium	0.62	0.62
Sodium	16.4	18.7
Zinc	0.015	0.015
Cadmium	0.005	0.005
Manganese	0.99	1.35
Cobalt	0.04	0.04
Copper	0.005	0.010
Iron	0.36	0.44
Lead	0.21	0.25
Chromium	0.05	0.04
Nickel	0.02	0.02
Conductivity	2300	2300
Sum Anions	29.6	29.2
Sum Cations	30.2	31.5
% Difference	1.0	2.6

Colorimetrically, nitrite was determined using the azo dye method (APHA, 1983, Section 419). Nitrate was determined colorimetrically by the brucine method (APHA 1971, Section 213C). For most samples, the sum of NO_3^- plus NO_2^- is reported.

Ammonia was determined by the automated phenate method without digestion. Total kjeldahl nitrogen (TKN) is determined by digestion with mercuric oxide, sulphuric acid, and potassium persulphate, (APHA, 1983 Section 420) to form ammonia and measurement of total ammonia in the sample by Nesslerization.

(b) Phosphorus

Soluble reactive phosphorus was determined by colour development using stannous chloride reduction (APHA, 1983 Section 424E). Orthophosphorus was determined by ion chromatography.

Total phosphorus was converted by digestion with sulphuric acid and potassium persulphate (APHA, 1983 Section 424C) to the soluble form whereupon an SRP determination was made.

(c) TOC, TIC

Total organic (TOC) and total inorganic (TIC) carbon were determined using a Beckman 915A Total Carbon Analyser and 865 Infrared Analyser. TOC involves stripping the inorganic carbon from the sample and measuring the CO_2 by IR after catalytic oxidation of the remaining organic carbon. TIC was determined as CO_2 by IR as well, after releasing the inorganic carbon on a bed of phosphoric acid coated quartz, at a lower temperature.

(ix) Physical Parameters on Liquid Samples

(a) Suspended and Dissolved Solids

Suspended solids were determined by filtering up to 200 ml of sample through a GF/C glass fibre filter and drying at 105°C to a constant weight. Dissolved solids were determined by drying a portion of the filtrate from suspended solids analysis at 105°C to a constant weight. Total solids were the sum of the above.

(b) Colour and Turbidity

Colour was determined by visual comparison to Co-Pt standards. Turbidity was determined by measuring the light, scattered at right angles, from a tungsten light source using a HACH 2100 turbidimeter.

(x) pH

pH measurement on liquid samples was made using an Orion pH meter calibrated with pH=4 and pH=7 standards, prior to reading the samples.

pH of soils and solids was made by slurrying the solids sample with enough distilled water to allow immersion of electrodes. After fifteen minutes a reading was taken. (Allen et al, 1974; Section 4.4).

(xi) Sulphur

(a) Sulphur Species - Liquids

The methylene blue colour comparison method was used to determine sulphide (APHA, 1983 Section 427).

Sulphate was analyzed by IC or by wet methods. Reduced sulphur species were determined by oxidizing the sample with sodium carbonate, nitric and hydrochloric acids and analyzing the sample for sulphate, turbidimetrically (APHA, 1983; Section 420C). The difference between this sulphate level and that obtained without the digest represents the reduced sulphur concentration.

(b) Sulphur - Solids

Total sulphur and sulphide were determined directly using a Leco combustion technique. This technique uses combustion of the total sample in a stream of oxygen and subsequent determination of the evolved SO_2 by infrared detection for total sulphur. For sulphide an portion was leached with distilled water until the conductivity of the leach water was less than 50 umhos/cm. The latter procedure removes the sulphate present, and the resulting total sulphur determination on remaining residue yields sulphide sulphur. This method is valid under the assumption that there is no native sulphur or organically-bound sulphur present in the samples. The best limit of detection obtainable by this method is 20 ppm as sulphur in both cases.

2.1.2 Quality Assurance Program (BEAK Laboratories)

The following quality assurance program was developed by BEAK to be cost effective yet sufficient to meet the needs of the specialized and varied workload encountered.

Principles

Production of quality data does not occur automatically and is not guaranteed by following any one or even several established procedures. Quality is achieved by dedicated effort, by careful attention to detail, and by practicing recognized principles of quality assurance. These efforts are accompanied by a desire for excellence and professional pride which creates an atmosphere conducive to ensuring quality.

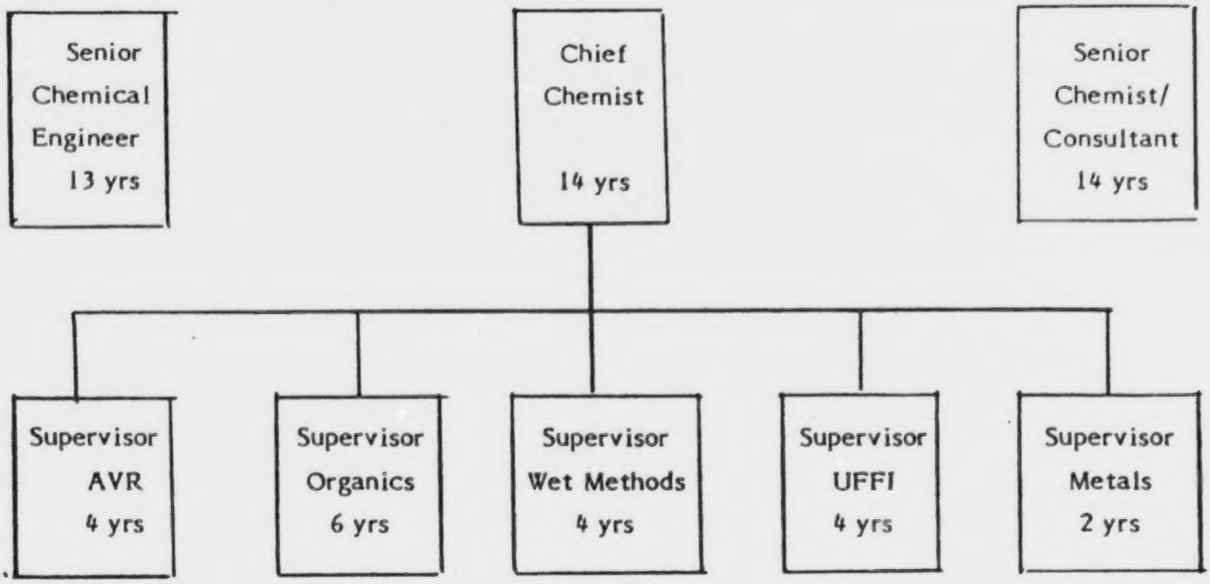
Sample Collection and Preservation

Any study requiring analytical tests to be carried out must address the collection of representative samples and the appropriate preservation of constituents for shipping. Standardization of the analytical techniques has been established to a high degree in our laboratory but the result of analysis is only as good as the sampling and sample preservation.

The following preservation techniques were recommended for:

- solid samples: keep cool;
- redox sensitive parameters: appropriate sampling and immediate measurement in a field laboratory;
- liquid samples;
  - preserve metals samples in plastic bottles with 5 ml of 50% nitric acid per litre,
  - nutrients - preserve with 5 ml of 50% sulphuric acid per litre,

FIGURE 2.1 LABORATORY ORGANIZATION (BEAK)


Senior Chemical Engineer 13 yrs
Chief Chemist 14 yrs
Senior Chemist/ Consultant 14 yrs
Supervisor AVR 4 yrs
Supervisor Organics 6 yrs
Supervisor Wet Methods 4 yrs
Supervisor UFFI 4 yrs
Supervisor Metals 2 yrs

- o TIC/TOC - sample into an air tight bottle and keep cool (4^oC),
- o anions - no preservative but keep cool (4^oC.

Sample Handling and Storage

Samples arriving in the laboratory underwent inspection and documentation:

- o the laboratory supervisor checked to make sure sampling instructions were followed,
- o samples were identified and recorded on laboratory sheets (4 digit code) in the receiving area and transmittal documents were filed,
- o samples were stored in a walk-in-cooler or in a freezer if required,
- o the senior chemist or chief chemist inspected all difficult samples (heterogeneous, mixtures, solids) and advised on subsampling/analytical verification procedures,
- o samples were monitored for subsampling bias, and
- o replicate samples were stored for future confirmation.

Laboratory Methods

Several analytical manuals/references were in routine use with analytical instrument operation manuals. The specific methods were described above. Special points include the following.

- o each wet chemical parameter has its own binder with printed instruction, reporting tables, graphs and calculations,
- o blank, standards, duplicates and reference solutions or reference materials were processed with each batch,
- o spikes were processed occasionally with difficult samples,
- o blind field duplicates were analyzed,
- o method conditions were compared with past acceptable performance range from other projects,
- o automated instruments, such as the DCP for metals have special calibration and reporting procedures (e.g., selecting appropriate wavelengths for measuring a metal where the primary wavelength is interfered by another element),
- o data were reviewed by the analyst and the supervisor to check for inconsistencies and precision and accuracy against references; questionable data was reanalyzed, and

- o the senior chemist periodically reviewed implementation of QC, method performance and bias, accuracy, consistency and format.

Summary of Internal Quality Assurance Program Used in this Study

For solids, a reference standard (CANMET tailings UTS-1 to UTS-5 or appropriate standard) was analyzed for every twenty samples. For liquids, standard solutions for cations and anions of interest were analyzed every 15 to 20 samples. The DCP was calibrated daily. Electroneutrality balances were calculated on solutions where possible. An acceptable standard was judged to be ± 5% in concentrated waters and ± 10% in dilute systems, if the analysis was on the same bottle. If catons were analyzed on an acidified sample, and anions on a filtered unpreserved sample, different criteria must be employed.

Measured Values for Reference standards are given in Table 2.2c.

TABLE 2.2c: MEASUREMENTS OF REFERENCE STANDARDS BY BEAK LABORATORIES FOR 1985 FOR NUTP MONITORING PROJECT

VII: EPA Reference 384, No. 7

	Value	June 1985	July 1985	Aug 1985	Measured Sept 1985	Oct 1985	Nov 1985	Dec 1985
Calcium	(40.6)	41	41	43/42/42	38/39	44	40	41/42
Magnesium	(8.4)	8.7	9.0	9.4/9.4/9.4	9.4/9.5	10.0	10.1	9.8/10.3
Potassium	(9.8)	9.8	9.9	10.5/10.3/10.0	10.9/10.2	10.6	10.8	10.6/10.5
Sodium	(46.5)	41	45	43/43/43	44/43	42	44	43/45

VIII: EPA Reference 581, No. 7

		Measured	
	Value	July 1985	Sept 1985
Molybdenum	(1.70)	1.86	1.76
Calcium	(0.50)	0.66	0.49
Magnesium	(0.10)	0.22	0.08
Barium	(1.20)	1.29	1.17
Potassium	(0.20)	-	0.26
Sodium	(0.09)	-	-

IX: EPA Reference 581, No. 2

		Measured	
Value	Aug 1985	Oct 1985	Nov 1985
(10.0)	10.7	10.5	10.8
(7.50)	7.6	6.8	7.0
(0.50)*	1.02	1.04	1.05
(10.0)	12	10	10
(1.50)	1.9	1.9	1.8
(1.50)**	3.1	3.3	2.5

X: ICAP Reference 1083, No. 7

	Value	Measured Dec 985
Aluminum	(0.97)	1.15/1.16
Barium	(0.97)	1.01/0.98
Potassium	(10.0)	11.3/11.4
Sodium	(0.86)	-/-

XI: EPA Reference 475, No. 6

	Value	Measured Jan 1985
Beryllium	(0.90)	0.84
Vanadium	(0.85)	0.62
Aluminum	(0.80)	0.52

XII: MBSS and BCSS References

	MESS Value	Feb 1985	BCSS Value	Feb 1985	June 1985
Zinc	(191)	187	(119)	113	130
Cadmium	(0.59)	2	(0.25)	L 2	-
Manganese	(513)	450	(229)	210	220
Cobalt	(10.8)	8	(11.4)	12	15
Copper	(25.1)	23	(18.5)	17	21
Iron	(30,500)	28,800	(32,900)	32,000	32,000
Lead	(34.0)	29	(22.7)	19	38
Chromium	(71)	65	(123)	119	132
Nickel	(29.5)	29	(55.3)	58	63

		Jan 1985	May 1985		Jan 1985	Sept 1985
Aluminum	(58,400)	36,800	40,000	(62,600)	38,200	45,800
Beryllium	(1.9)	2	3	(1.3)	2	3
Molybdenum	(2.2)	L 2	-	(1.9)	L 2	-
Calcium	(4,820)	2,600	3,200	(5,430)	2,900	3,300
Vanadium	(72.4)	80	81	(93.4)	99	96
Magnesium	(8,680)	5,300	7,200	(14,720)	9,100	11,500
Barium	-	180	220	-	186	200
Potassium	(18,600)	13,600	19,800	(18,010)	13,400	13,900
Strontium	(89)	45	62	(96)	50	57
Sodium	(18,550)	15,000	18,300	(20,180)	16,100	16,800

2.2 Barringer Laboratories

Barringer Magenta Laboratories (Mississauga, Ontario) was the check laboratory for analyses of non-radionuclide parameters in surface water samples.

2.2.1 Laboratory Methods of Analysis (Barringer Laboratories)

The analytical methods described in this section are well established, published methods for the analysis of the parameters in question. They are very similar to the methods described in the following standard publications: APHA, (15th Edition, 1983); Environment Canada (1971); Rudolf Bock (1979); ASTM (1979); and Ontario Ministry of Environment (1984). A summary of the methods used and corresponding limits of detection are presented in Tables 2.3(a) and 2.3(b).

Surface Water - Metals

Porewater samples were analyzed for metals by ICAP. The detection limits have been given in Table 2.3(b). If copper was near the detection level, the samples were reanalyzed by flame atomic absorption to confirm the levels at a 0.005 mg/l detection level.

Arsenic and selenium were determined by heated quartz tube flameless atomic absorption following sodium borohydride-induced hydride formation. The detection limits from porewater tests are as shown in Table 2.3.

Surface Water - Anions

The anions were determined by ion chromatography using a Dionex model 2110i system with the detection limits given in Table 2.3. The detection limits are based upon analysis of pure solutions. Samples were ordinarily diluted, in order to bring the sulphate into analytically measureable ranges.

TABLE 2.3a: METHODS AND DETECTION LIMITS FOR REQUIRED CHEMICAL ANALYSES (BARRINGER)

	Waters	
Parameter	Detection Limit	Method
F^-	0.005 mg/L	I.C.
Cl^-	0.01 mg/L	I.C.
$PO_4^=$	0.05 mg/L	I.C.
Br^-	0.05 mg/L	I.C.
NO_3^-	0.05 mg/L	I.C.
$SO_4^=$	0.05 mg/L	I.C.
Ortho-P	0.005 mg/L	Colorimetry
Total-P	0.005 mg/L	Colorimetry
NO_3^-	0.005 mg/L	Colorimetry
TKN	0.05 mg/L N	Colorimetry
NH_3	0.05 mg/L N	Colorimetry
As	0.001 mg/L	Hydride-A.A.
Se	0.001 mg/L	Hydride-A.A.
Colour	10 S.C.U.	Visual
Turbidity	10 N.T.U.	Fluorescence
T.D.S.	1 mg/L	Gravimetry
T.S.D.	1 mg/L	Gravimetry
T.O.C.	0.2 mg/L	IEC BEAK
T.I.C.	0.2 mg/L	IEC BEAK

TABLE 2.3b: ANALYTICAL DETECTION LIMITS FOR I.C.A.P. METAL SCAN*

Element	Detection Limits	
	Waters (mg/L)**	Solids (ppm)***
Ag	0.005	0.1
Al	0.05	1
B	0.005	4
Ba	0.005	0.1
Be	0.0005	0.01
Ca	0.05	1
Cd	0.01	0.2
Co	0.05	1
Cr	0.01	0.2
Cu	0.01	0.2
Fe	0.01	0.2
K	1.0	20
Mg	0.01	0.2
Mn	0.01	0.2
Mo	0.2	4
Na	1.0	20
Ni	0.05	1
P	0.5	10
Pb	0.05	1
Si	0.05	50
Sr	0.001	0.02
Th	0.05	1
Ti	0.005	0.1
V	0.005	0.1
Zn	0.05	1
Zr	0.02	0.4

* Detection limit is for pure solution, not for matrix of samples analyzed in this study.

** If acid digestion is required, Si, Ba and B are not reported.

*** Based on $HF/HClO_4HNO_3$ digestion of sample.

Surface Water - Nitrogen Species

Ammonia nitrogen was determined using an automated phenate colorimetric procedure. The detection limit is 0.05 mg/l as nitrogen.

Surface Water - Nutrients

Total phosphorus and Kjeldahl nitrogen were determined colorimetrically (Ontario Ministry of the Environment, 1984). This procedure was generally used because orthophosphate was below the detection limit of ion chromatography. The sample was first acid digested. For TKN, a phenate colour development followed. For phosphorus and ascorbic acid, reduced antimony-tartarate colour development was used. Ammonia was determined by the phenate method without the digest. Nitrate was determined by the azo dye method following a cadmium reduction, in a few spot samples.

Surface Water - TOC/TIC

Total organic and inorganic carbon was determined using the Beckman I.R. technique, and was subcontracted to Beak Analytical Serices.

Surface Water - Physical Parameters

The determination of solids involved filtering a 200 ml sample through a 0.45 um membrane filter. The filtrate was evaporated and dried to constant weight. The residue was weighed to determine the dissolved solids content. An unfiltered sample was evaporated and dried and the residue weighed to give the total solids content. The difference represents the suspended solids concentration.

Colour was determined by visual comparison to Co-Pt standards and turbidity was measured by light scattering.

2.2.2 Quality Assurance/Quality Control Program (Barringer Laboratories)

Summary of Program

Samples which enter the laboratory were logged in a centralized filling system and issued a work order number prior to being forwarded to the appropriate laboratory section. An updated work order log was maintained on a computer system for quick reference. All laboratory staff kept records of all work in personal laboratory notebooks.

Routine quality control practice involved the analysis of one control sample for every 10 to 15 samples analyzed. The control sample is either a reagent blank, sample replicate or a certified reference material (if available). The reagent blank was used to monitor any possible sources of contamination in the reagents or glassware used or inherent in the method used. The analysis of sample replicates gave an indication of the analytical precision and/or the sample homogeneity. The reference material was employed primarily as an accuracy control but it could also provide a check on analytical precision and recoveries. If the sample replicate showed larger deviations than expected, and if a sufficient number of replicates of the reference material were included in the batch, the results could be used to determine the analytical precision of the technique. Because reference materials should, by design, be more homogenous than actual samples, sample imprecision may simply reflect inhomogeneity, caused by inadequate preparation procedures or an insufficient aliquot of the sample being measured.

In this project, the reference materials used are presented in Table 2.5.

The solid samples were analyzed along with a series of reference materials which are deemed most appropriate for the particular type of matrix. Reference materials for the solids analyses were chosen to match the sample matrices as closely as possible. The tailings solids were matched by using standards from a certification program issued in 1983. These are UTS-1 through to UTS-4. These have been analyzed previously by Barringer for metals (ICAP and AAS, Th, U, S and $SO_4^=$). In addition, other uranium ores and rock standards were also available for use in this regard.

Laboratory Performance Evaluation

Barringer participated in a wide variety of Interlaboratory comparison programs. Relevant programs include the US EPA; Environment Canada and the CANMET Certified Reference Material Program.

2.2.2 Results of QA/QC Program (Barringer)

Results of the QA/QC Program of Barringer are given in Table 2.4. Measurements of reference samples can be compared directly to certified values in the Table. Replication of certain samples are given in Table 2.4d for anions, As and Se.

These data were generated as part of the Lacnor program; Gunnar samples for check analysis by Barringer were typically submitted at the same time as submission of Lacnor samples. Hence these data are representative of the QA program of Barringer.

TABLE 2.4a: BARRINGER METAL SCAN QA (Ag to Cr)

Report Date	Sample I.D.	Ag (ppm)	Al (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)
21 May 85	ERA STD	L 0.005	0.18	0.200	0.219	0.0492	L 0.01	0.05	0.15	0.07
	ERA STD	L 0.005	0.19	0.195	0.231	0.0488	0.03	0.04	0.14	0.07
	Certified Value	-	0.20	-	-	0.053	-	0.04	0.16	0.07
06 Jun 85	ERA STD	L 0.005	0.18	0.181	0.146	0.0475	L 0.01	0.04	0.16	0.07
	ERA STD	0.017	0.17	0.172	0.169	0.0465	0.04	0.05	0.16	0.07
	ERA STD	L 0.005	0.16	0.176	0.189	0.0481	L 0.01	0.05	0.14	0.07
08 Aug 85	ERA STD	L 0.005	0.25	0.183	0.198	0.0488	L 0.01	0.04	0.15	0.07
12 Dec 85	EPA TRACE 2	L 0.005	0.80	L 0.004	0.014	0.235	L 0.01	0.04	0.33	0.28
	EPA TRACE 2	L 0.005	0.81	0.012	0.014	0.237	L 0.01	0.04	0.32	0.28
	Certified Value	-	0.73	-	-	0.235	-	0.039	0.26	0.26
04 Oct 85	CITRUS LEAF	L 0.3	32.1	27.0	16.3	0.03	29,600	L 0.5	L 3	1.9
	Certified Value	-	92	-	21	-	31,500	0.03	0.02	0.8

TABLE 2.4b: BARRINGER METAL SCAN QA (Cu to Pb)

Report Date	Sample I.D.	Cu (ppm)	Fe (ppm)	K (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)
21 May 85	ERA STD	0.113	0.20	L 1	L 0.01	0.07	0.3	L 1	0.21	L 0.5	
	ERA STD	0.112	0.22	L 1	L 0.01	0.07	0.3	L 1	0.20	L 0.5	
	Certified Value	0.117	0.21	-	-	0.08	0.3	-	0.22	-	
06 Jun 85	ERA STD	0.115	0.20	L 1	L 0.01	0.07	0.3	L 1	0.21	L 0.5	
	ERA STD	0.111	0.20	L 1	L 0.01	0.07	0.3	L 1	0.23	L 0.5	
	ERA STD	0.116	0.20	L 1	L 0.01	0.07	0.2	L 1	0.20	L 0.5	
08 Aug 85	ERA STD	0.113	0.17	L 1	L 0.01	0.07	0.2	L 1	0.23	L 0.5	
12 Dec 85	EPA TRACE 2	0.331	0.79	L 1	0.01	0.33	L 0.2	1	0.21	L 0.5	
	EPA TRACE 2	0.336	0.77	1	L 0.01	0.34	L 0.2	1	0.21	L 0.5	0.44
	Certified Value	0.339	-	-	-	0.348	-	-	0.207	-	0.435
04 Oct 85	CITRUS LEAF	13.9	69.9	16,600	5,540	17.2	10	150	5	1,160	
	Certified Value	16.5	90	18,200	5,800	23	0.17	160	0.6	1,300	

TABLE 2.4c: BARRINGER METAL SCAN QA (Si to Zr)

Report Date	Sample I.D.	Si (ppm)	Sr (ppm)	Th (ppm)	Ti (ppm)	V (ppm)	Zn (ppm)	Zr (ppm)
02 May 85	ERA STD	0.37	L 0.001	0.06	0.214	0.303	0.25	L 0.05
	ERA STD	0.36	L 0.001	L 0.05	0.215	0.293	0.24	L 0.05
	Certified Value	-	-	-	0.228	0.317	0.25	-
06 Jun 85	ERA STD	0.08	L 0.001	L 0.05	0.215	0.324	0.26	L 0.05
	ERA STD	0.07	L 0.001	L 0.05	0.208	0.329	0.27	L 0.05
	ERA STD	0.07	L 0.001	L 0.05	0.220	0.328	0.27	L 0.05
08 Aug 85	ERA STD	0.45	L 0.001	L 0.05	0.224	0.324	0.25	L 0.05
12 Dec 85	EPA TRACE 2	0.17	L 0.001	0.05	L 0.005	0.883	0.45	L 0.05
	EPA TRACE 2	0.18	L 0.001	0.08	L 0.005	0.906	0.46	L 0.05
	Certified Value	-	-	-	-	0.846	0.418	-
04 Oct 85	CITRUS LEAF	110	93.1	13	4.1	L 0.3	24	L 3
	Certified Value	-	100	-	-	-	29	-

TABLE 2.4d: BARRINGER QA FOR ANIONS, As and Se, IN SURFACE WATERS

Lab I.D.	Sample I.D.	F (mg/L)	Cl (mg/L)	NO_2 (mg/L)	PO_4 (mg/L)	Br (mg/L)	NO_3 (mg/L)	SO_4 (mg/L)	As (ug/L)	Se (ug/L)	NH_3-N (mg/L)
	Surface Water										
328	GW-02/I	3.70	11.0	L 2	L 10	L 10	L 5	6,650	20	L 1	3.6
	GW-02/I Repeat	3.90	13.0	L 2	L 10	L 10	L 5	6,490	21	L 1	3.5
	GW-05/I	3.10	26.0	L 2	L 10	L 10	L 5	4,570	4	L 1	4.6
	GW-05/I Repeat	3.90	28.0	L 2	L 10	L 10	L 5	4,510	4	L 1	4.4
546	GW-03-G	3.24	117	L 0.2	L 1	L 0.5	L 5	3,320	-	L 1	3.81
	GW-03-G Repeat	3.18	117	L 0.2	L 1	1.0	L 5	3,270	-	L 1	4.01
	GW-04-A								L 1		
	GW-04-A Repeat								L 1		

2.3 Monenco Laboratories, Calgary, Alberta

For the Gunnar program, Monenco conducted the radionuclide analyses for;

- Tailings solids - check laboratory
- Tailings porewater - check samples
- Surface water - major laboratory
- Atmospheric Dust - check laboratory
- Biological and vegetation tissues - major laboratory

2.3.1 Summary of Analytical Methods (Monenco)

Sample Preservation and Preparation

Liquids: Water samples for dissolved radionuclide analysis were assumed to have been field-filtered and preserved prior to shipment to the laboratory. Any water samples for total radionuclide analysis were also acidified in the field; they were subsequently digested in the laboratory prior to analysis.

Solids: Solids were dried at 50°C and ground to ensure sample homogeneity. Prior to drying the moisture content was measured. Solid samples were dissolved by KF-pyrosulfate fusion for the determination of radium and thorium and by digestion using a hot concentrated mixture of nitric, perchloric and hydrofluoric acids, followed by a pyrosulfate fusion for the determination of lead and polonium. Subsamples for radionuclide analysis exceeded 0.5 gms in order to minimize uncertainty due to the counting statistics.

Summary of Analytical Methods

All samples were analysed according to the procedures outlined in the "Analytical Methods Manual-National Uranium Tailings Program" by Dean and Chiu, 1984. They are in summary:

Radium-226, Radium-223 - High Resolution Alpha Spectrometry (HRAS) (Ba-133 Tracer).

Th-232, Th-230, Th-228 - HRAS (Th-234 tracer).

Radium-228 - indirect measurement of daughter, Actinium 228, a beta emitter.

Lead-210 - indirect measurement of daughter, bismuth-210, a beta emitter.

Polonium-210 - HRAS (Po-208 tracer).

Uranium - delayed neutron activation (solids), fluorimetry (liquids).
Uranium Ratio
(U-234, U-234, U-238) - HRAS (after isolation of uranium).

Specific Analytical Procedures

Pb-210

Summary: Indirect measurement of daughter, bismuth-210.

Method: One must allow 30 days for the ingrowth of Bi-210, a beta emitter, to achieve an equilibrium of greater than 98%. A carrier solution of stable lead and bismuth was added prior to digestion. Bismuth was then solvent-extracted, subsequently precipitated as bismuth oxychloride and beta-counted to measure Bi-210, the first daughter of Pb-210. The absolute detection limit for Pb-210 was 0.05 Bq. (Dean and Chiu, 1984).

Po-210

Summary: Polonium-210 - HRAS (Po-208 Tracer).

Method: A tracer solution of Po-208 was added prior to digestion. The polonium isotopes were deposited on a nickel disc and determined by alpha spectroscopy. The overall chemical yield was determined by the recovery factor Po-208. The detection limit for Po-210 was 0.01 Bq.

Ra-226

Summary: Radium-226, Radium-223 - High Resolution Alpha Spectrometry (HRAS) (BA-133 Tracer).

Method: A tracer solution of Ba-133 was added prior to digestion. Radium was coprecipitated with $PbSO_4$, subsequently dissolved and isolated by coprecipitation with $BaSO_4$. The overall chemical yield was determined by gamma counting of Ba-133; Ra-226 was then determined by alpha spectroscopy. The detection limit for Ra-226 was 0.01 Bq. (Dean and Chiu, 1984).

Ra-228

Summary: Indirect measurement of daughter, Actinium-228, a beta emitter.

Method: Radium-228 and other radium isotopes were separated by coprecipitation with lead sulphate, re-dissolved and purified by coprecipitation with barium sulphate. The barium (radium) sulphate was stored to allow the ingrowth of Ac-228, the first daughter of Ra-228 and known to grow into equilibrium with Ra-228 by virtue of its short half life. Actinium-228 was then separated from the radium isotopes by coprecipitation with cerous hydroxide which was then beta-counted to a detection limit of 0.05 Bq. (Dean and Chiu, 1984).

Ra-223

Summary: High Resolution Alpha Spectrometry (HRAS, BA-133 Tracer).

Method: Radium isotopes were collected as described for Ra-226 and determined by alpha spectroscopy. While the alpha energy of Ra-226 was clearly separate from Ra-223 and Ra-224, the alpha energies of these latter two isotopes (5.71 and 5.68 MeV respectively) are too close to permit resolution. In the natural environment, Ra-224 was not expected to be present in significant amounts but it was found to occur in waste tailings streams in other NUTP projects. In such cases, its presence affected the precision of the Ra-223 measurement. The Ra-224 contribution, if any, was quantified and subtracted by measurement of its daughter products Bi-212 and Po-212 by alpha counting techniques. The detection limit of Ra-223 was 0.05 Bq. Dean and Chiu, (1984).

Th-232, Th-230, Th-228

Summary: HRAS (Th-234 tracer)

Methods: A tracer solution of Th-234 was added prior to digestion. Thorium was co-precipitated with $PbSO_4$, isolated by solvent extraction, and then co-precipitated with cerous hydroxide. The thorium precipitate was then beta-counted for Th-234 to measure the overall yield and then Th-230, Th-232 and Th-228 were determined by alpha spectroscopy. The detection limit for Th-230, Th-232, and Th-228 was 0.01 Bq. Dean and Chiu, 1984.

Uranium - Total

Summary: Fluorimetry (liquids) delayed neutron activation (solids).

Method: In liquid samples, natural uranium was determined fluorimetrically as its fluoride complex following fusion with sodium fluoride-lithium fluoride. In solid samples, U was determined by DNA. The detection limit for uranium was 0.1 ug. (Dean and Chiu, 1984).

Uranium Ratio

Summary: Uranium Ratio (U-234/U-238:HRAS after isolation of uranium.

Method: Uranium was chemically separated from a water sample by co-precipitation with aluminum phosphate, solvent extraction and co-precipitated with cerous fluoride. U-238, U-234, and U-235 (if required) were determined by alpha spectroscopy. (Dean and Chiu, 1984; Sill and Williams 1981).

Detection Limits

Detection limits for various radionuclides are given in Table 2.5. The mass of each isotope measured is so small that one does not have a "normal operating range" or a "bias" (versus true value), such as one would encounter for chemical methods of analysis for cations and anions (see Table 2.1). Accordingly, the routine analytical operating range is not given because it is not meaningful.

2.3.2 Quality Assurance and Quality Control Program (Monenco)

Quality Assurance Program

The quality assurance program for radiochemistry of solids involved the analysis of one or two CANMET reference materials (UTS-1 to UTS-5) or reference ore (e.g., DL-1, DL-2, etc.) for every 15-20 field samples analysed. For liquids, one reference solution is used for up to 10 samples in a batch for Ra-226, Th isotopes, and Po-210. Two reference solutions are used for up to 10 samples for Ra-228 and Po210 determinations. In addition, the alpha spectrometers, gamma spectrometers and beta spectrometers were calibrated daily.

One replicate analysis per batch of 15-20 samples was made. A tracer was added to every sample, reference solution, or certified reference to check recovery.

Laboratory Quality Control Program

The quality control program which attempts to assure the scientific reliability of the laboratory data, used management, administrative, statistical, investigative, preventive and corrective techniques to maximize reliability of the data.

It involved:

- o the publication and distribution of current and complete analytical methods and procedures and analytical instrument operating instructions;
- o the distribution and retention of laboratory reports with provision for administrative technical review;

- Quality control checks on analytical instruments to ensure proper function at all times;
- a Preventive Maintainence Program; and
- an analytical quality control system to ensure continued precision and accuracy of laboratory results. This includes:

    a) daily instrument calibration with standards,
    b) where available, control samples included with each run. A control sample is one that has a similar matrix and has a working value established by organizations such as ASTM or APHA,
    c) when a control sample is not available, a previously run unknown is included as a blind check sample,
    d) a reagent blank is analysed for all parameter determinations,
    e) if the results attained for the control or recycle samples are not within acceptable limits, the entire batch of analyses are repeated and control verified before reports are issued,
    f) policy (e) is based on the presence of large enough samples. When such is not the case two options are available:
        (i) non-acceptance of the analysis by the laboratory, or
        (ii) waiving of the quality control actions by the client.
- Participation in inter-laboratory quality evaluation programs.
- All personnel trained and qualified in quality control techniques prior to running new analyses.

Organization of Laboratory Quality Control Progam

Figure 2.2 shows the organization of the quality control program. The quality control coordinator reports to the lab manager. Each section has its own quality control program and is under the administration of the coordinator.

Duties of Coordinator

- Responsiblity of Q.C. program and for taking or recommending Q.C. measures to ensure accuracy and precision of data produced.
- Develops statistical procedures and techniques and supervises their use.

TABLE 2.5a: OPERATING CHARACTERISTICS OF RADIONUCLIDE ANALYSIS FOR WATER (Routine Procedure)

Parameter	Unit of Measurement	Best Method Lowest Reported Value*
Total U	ug/L (ppb)	0.5
U-238	not applicable	-
U-234	(activity ratio measured)	-
Th-230	Bq/L	0.005
Ra-226	Bq/L	0.005
Pb-210	Bq/L	0.1
Po-210	Bq/L	0.005
Th-232	Bq/L	0.005
Ra-228	Bq/L	0.1
Th-228	Bq/L	0.005

* Assuming 1 litre sample size.

TABLE 2.5b: OPERATING CHARACTERISTICS OF RADIONUCLIDE ANALYSIS FOR SOLIDS (Routine Procedure)

Parameter	Unit of Measurement	Best Method Lowest Reported Value*
Total U	ug/g	0.5
U-238	(activity ratio measured)	-
U-234	(activity ratio measured)	-
Th-230	Bq/g	0.005
Ra-226	Bq/g	0.005
Pb-210	Bq/g	0.1
Po-210	Bq/g	0.005
Th-232	Bq/g	0.005
Ra-228	Bq/g	0.1
Th-228	Bq/g	0.005

* Assuming 1 gm sample size.

TABLE 2.5c: OPERATING CHARACTERISTICS OF RADIONUCLIDE ANALYSIS FOR SEDIMENT (Routine Procedure)

Parameter	Unit of Measurement	Best Method Lowest Reported Value*
Total U	ug/g (ppb)	0.5
U-238	not applicable	-
U-234	not applicable	-
Th-230	Bq/g	0.005
Ra-226	Bq/g	0.005
Pb-210	Bq/g	0.10
Po-210	Bq/g	0.005
Th-232	Bq/g	0.005
Ra-228	Bq/g	0.10
Th-228	Bq/g	0.005

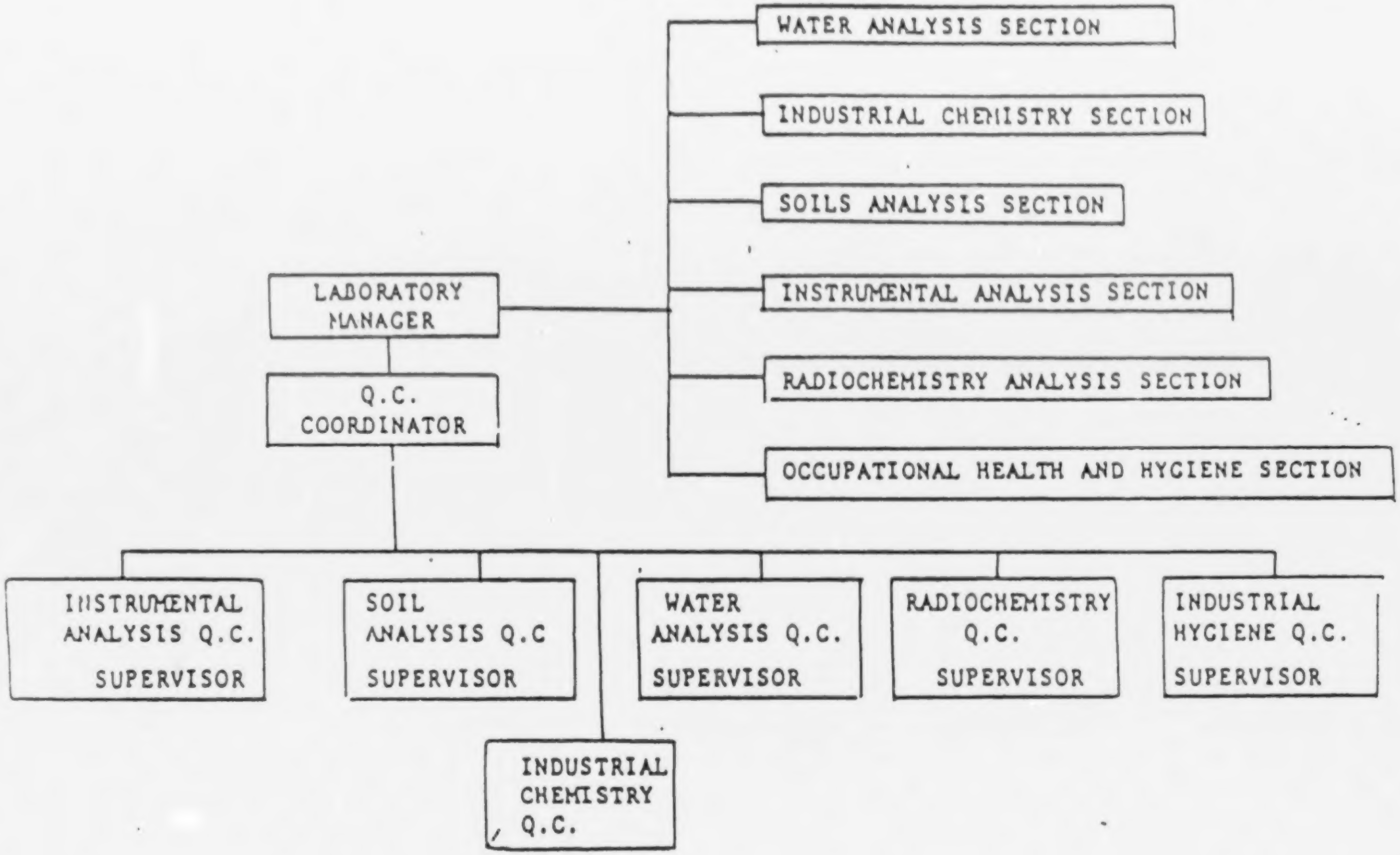
* Assuming 1 gm sample size.

TABLE 2.5d: OPERATING CHARACTERISTICS OF RADIONUCLIDE ANALYSIS FOR FISH (Routine Procedure)

Parameter	Unit of Measurement	Best Method Lowest Reported Value*
Total U	ug/kg tissue	10
U-238		
U-234		
Th-230	Bq/kg	5
Ra-226	Bq/kg	5
Pb-210	Bq/kg	0100
Po-210	Bq/kg	5
Th-232	Bq/kg	5
Ra-228	Bq/kg	100
Th-228	Bq/kg	5

* Depends on sample size available and method of sample dissolution, i.e., whether dry ashed or wet digested. These numbers assume 1.0 gm wet weight digested, and used for analysis of one individual isotope.

FIGURE 2.2: LABORATORY QUALITY CONTROL ORGANIZATION (MONENCO)


LABORATORY MANAGER
Q.C. COORDINATOR
WATER ANALYSIS SECTION
INDUSTRIAL CHEMISTRY SECTION
SOILS ANALYSIS SECTION
INSTRUMENTAL ANALYSIS SECTION
RADIOCHEMISTRY ANALYSIS SECTION
OCCUPATIONAL HEALTH AND HYGIENE SECTION
INSTRUMENTAL ANALYSIS Q.C. SUPERVISOR
SOIL ANALYSIS Q.C SUPERVISOR
WATER ANALYSIS Q.C. SUPERVISOR
RADIOCHEMISTRY Q.C. SUPERVISOR
INDUSTRIAL HYGIENE Q.C. SUPERVISOR
INDUSTRIAL CHEMISTRY Q.C.

- Seeks out and evaluates new ideas in Q.C.
- Monitors Q.C. program.
- Advises lab manager in reviewing technology methods and equipment with respect to Q.C. aspects.
- Recommends laboratory safety and occupational hygiene measures.

Duties of Q.C. Supervisor

- Carry out monitoring, record keeping, statistical techniques and other functions required.

Quality Control Operating Principles

Record Keeping: Each sample is assigned a laboratory number and the analysis parameters requested are tabulated in a log book.

Reporting Practice: Each analysis report is prepared in triplicate. One copy is sent to the client and the other copies are filed in the specific project file. All raw data used to calculate each parameter are filed and stored in locations dedicated to that parameter and is retained for a period of two years. This practice allows re-checking of measurement data and calculation should it be necessary. Where possible, the estimated precisions of all data are included. Data obtained for standard reference materials and duplicates are also kept.

Sample Storage: Samples are routinely stored for a minimum of 6 months. When space is available, each sample is retained in storage for a period of two years.

Instrument Calibration: Prior to the measurement of a parameter for a batch of samples the instrument and method is calibrated using appropriate dilutions of certified reference solutions or sources. The calibration procedure and measurement methodology is documented for reference purposes, in internal laboratory handbooks.

Calibration Interval: Each method and instrument was calibrated each time a batch of samples was analysed and not less frequently than one per day. This interval is based on the degree of usage. All data and historical records pertaining to the calibration and maintenace of the instrumentation are retained for a period of 3 years.

Environmental Conditions: Laboratory conditions were controlled to the degree necessary to ensure required accuracy. The area was free of dust, vapours and vibration. Each instrument was not located close to equipment that produced vibration, chemical emissions or noise. The laboratory area was maintained at a temperature of 21-22°C. The analytical balances and electronic equipment for radiochemistry were located in an air conditioned environment with a filter air supply.

Preventive Maintenance: The preventative maintenance program included cleaning, lubricating, adjusting and testing of all instruments and visual and electronic examination of the instrumentation on a regular basis. Its purpose is to increase measurement system reliability.

Use of Certified Reference Materials: Reference materials used in this project have been summarized above. In circumstances where reasonable agreement between the known and found composition of the CRM is not obtained, than all samples analysed in that batch are reanalysed. Agreement is obtained prior to reporting of data. In circumstances where CRM's were not available, 5% of each sample batch were reanalysed and a sample that has been previously analysed and reported was substituted for the CRM.

Interlaboratory Testing Programs: Monenco participated in:

1) Environment Canada, 2) Alberta Environment, 3) Saskatchewan Environment, 4) Western Enviro-Agricultural Laboratories Association, 5) U.S. EPA, and 6) CANMET programs.

2.3.3 Results of QA Program

A comparison of the measured values of reference solutions to certified values are given in Table 2.5(d) for analysis of porewater and surface water samples by Monenco for the year 1985.

TABLE 2.6: RESULTS OF MONENCO QA/QC PROGRAM (1985) FOR REFERENCE AND CONTROL SAMPLES

Radionuclide	Reference Solution	Activity[1] (Bq/mL)	Result[2] (Bq/mL)
Ra-226	RAY.44[3]	0.99	0.97 to 1.02
Th-228	RLZ.44[3]	1.49	1.40 to 1.55
Po-210	RBZ.44[3]	3.52	3.40 to 3.60
Ra-228	$Th(NO_3)_4 \cdot 4H_2O$	4.08	3.75 to 4.25
Pb-210	RBZ.44[3]	3.52	3.30 to 3.70

[1] Sources prepared from 1 mL of these solutions are used daily to calibrate instrument.

[2] These reference solutions are routinely used as control samples. One control for up to ten samples for Ra-226, Th isotopes and Po-210 determinations. Two controls for Ra-228 and Pb-210 determinations. Control samples vary between 0.5 mL to 10 mL of reference solutions. This column gives results obtained in our lab during 1985.

[3] All obtained from Amersham Corporation.

2.4 Saskatchewan Research Council

Saskatchewan Research Council was the primary laboratory for analyses of radionuclide parameters for the following components:

- tailings porewater,
- tailings solids,
- atmospheric dust,
- biological tissues and vegetation;

and the main check laboratory for surface water analyses of radionuclides. SRC was the main check laboratory for analysis of non-radionuclide parameters for the following components:

- tailings porewater,
- tailings solids,
- surface water,
- atmospheric dust,
- biological tissues and vegetation.

2.4.1 Sample Preservation and Preparation

It was assumed by SRC that the following sample handling and preservation procedures were used by Field Personnel.

Recommended Sample Preservation Procedures After Sampling (SRC)

Radionuclides

Water: For each radionuclide determination, one litre of sample was preserved with 10 mL conc. HNO_3. If it was necessary to distinguish between dissolved and suspended species, an additional one litre was filtered with a 3 micron filter and then acidified to 1% HNO_3.

Vegetation: For one to four radionuclide determinations, a minimum of 100 grams was washed, air dried, and stored in a plastic bag.

Tissue: For one to four radionuclide determinations, a minimum of 500 grams was cleaned, gutted, skinned and/or plucked, stored in a plastic bag and frozen.

Solids: A minimum of 100 to 500 grams of rock, mud, soil, etc., was stored in a plastic bag or suitable container.

Water Samples - Other Parameters

Sulfide/Mercaptan:

Samples were preserved with NaOH pellets so that pH is greater than 13.

Sulphide(less than 1 ppm):

The container was filled to the top with sample allowing no air space and preserved with one gram ascorbic acid per 300 mL sample, and preserved with NaOH pellets so that pH was greater than 13.

Trace Metals:

Samples were preserved with 1% HNO_3.

Laboratory Sample Handling Procedures (SRC)

Preparation of Solids Samples: A minimum of 100 to 500 grams of rock, tailings, soil, sediment, etc., in a plastic bag or suitable container was stored as shipped. After drying, solid samples were ground in puck-and-ring grinders of hardened steel to a fine enough state to ensure representative sampling (95% minus 100 mesh). Sample digestion was either by HF treatment-pyrosulfate fusion or by mixed acid digestion ($HF-HCl-HNO_3-H_2SO_4$).

Preparation of Water Samples: Samples were stored in plastic containers. All water samples were analyzed as quickly as possible after receipt to minimize changes in chemical composition. If evaporation of water samples were required as a preconcentration step for trace metal determinations, extreme precautions were taken to prevent contamination or losses during this process.

Preparation of Biological Samples: The main biological sample types were fish and vegetation.

Fish/Tissue: Fish samples were prepared either as whole fish homogenates or as separate bone and flesh components depending on the sample size and the information required. After homogenizing or separating the samples they were dry ashed at temperatures below 550°C. The resulting ash was then dissolved in nitric acid or hydrochloric acid depending on the subsequent analytical procedure. For elements which may volatilize at the foregoing temperature the sample was dissolved directly in nitric-perchloric acids.

Vegetation: Vegetation was dry ashed or digested in nitric-perchloric acids depending on the subsequent analytical determination.

2.4.2 Laboratory Methods of Analysis (SRC)

Summary of Analytical Methods for Radionuclides

All radiochemical samples were analyzed according to the procedures outlined in the "Analytical Methods Manual for the National Uranium Tailings Program" by Dean and Chiu (1984) or a variation thereof. Variations are documented below.

Lead-210

The procedure used for the determination of lead-210 is detailed in CANMET Report 78-22 (p. 20) and was developed in the SRC Analytical Laboratory. The detection limit was 0.5 pCi (0.02 Bq). The precision was ±5% (1 sigma) for levels above 10 pCi (0.4 Bq).

Radium-226

Radium-226 was determined according to the gross alpha counting procedure in CANMET Report 78-22. Alpha spectroscopy was performed on representative samples to confirm the absence of Ra-223 and Ra-224 interferences. The detection limit for this procedure was 0.1 pCi (0.004 Bq). The precision at the 10 pCi (0.4 B1) level was approximately ±5% (1 sigma).

Thorium-230

The radiochemical procedure used for Th-230 is identical to that in the NUTP Analytical Procedures Manual (Dean and Chiu, 1984). After isolation, Th-230 was co-precipitated with $Ce(OH)_3$, filtered onto a fine pore-size membrane filter and measured by alpha spectroscopy. The detection limit was approximately 0.2 pCi (0.01 Bq). The precision at the 10 pCi (0.4 Bq) level was approximately ±7% (1 sigma).

Uranium

Uranium was determined by delayed neutron counting if the level is above 0.1 ug/g or 0.1 ug/mL. The precision of this method is ±2% (1 sigma) or levels above 10 ppm. Samples containing less than 0.1 ug/mL were analyzed by the conventional UV excited fluorescence method (Centanni et al, 1956). With a preconcentration of liquids this method can detect down to 0.5 ug/L. The precision was approximately ±8% (1 sigma) for levels above 20 ug/L.

Summary of Analytical Methods for Trace Metals

Trace metals were routinely determined by plasma emission spectrometry except for As and Se which were determined by atomic absorption spectrometry. Using a 5-fold preconcentration all metals could be detected below the 10 ug/L range and many at the 1 ug/L level. In the sub-ppm range both techniques had a relative standard deviation of approximately ±5% (1 sigma).

2.4.3 Quality Assurance/Control Program (SRC)

The SRC QA/QC program consists of use of reference samples and replicates, participation in interlaboratory comparison programs, sample logging procedures and recommendations for sample handling.

Quality Assurance - Replication and Use of Standards

Blind duplicates, spiked samples and blanks were routinely processed. These internal quality control checks constitute approximately 10% of the analytical workload. All radiochemical procedures were calibrated and checked with NBS traceable standards (some directly from NBS and others from Amersham).

There are no Q.C. checks for the radium-228 measurements other than the series of standards (aged thorium nitrate and Alfa thorium oxide, 30 years old) which were run with each group of samples. Normally, four standards and one blank were analyzed with each set. Over the years, these standards and some spiked samples have given an overall analytical precision of ±7% (1 sigma). In addition, SRC has always been within the control limits for the USEPA interlab Ra-226, 228 program for the last 6-7 years.

Standard reference materials include the following: CANMET Uranium Ore Reference Standards BL-1, BL-2, BL-3, BL-4, BL-4a, BL-5, DH-1, DH-1a, DL-1, DL-1a, CUP-1. CANMET Uranium Tailings Ref. Mat. UTS-1, UTS-2, UTS-3, UTS-4, UTS-5. CANMET Radiochemical Vegetation Ref. Mat. CLV-1, CLV-2. Amersham aged Thorium nitrate, ALFA thorium oxide, radium-226 solution RAY.44, barium-133 solution BDZ-72; lead-210 (polonium-210) solution RBZ.44; alpha ref. source AMR.33. National Bureau of Standards - radium-226 solution 4953-C. ICN CHemical and Isotope Division - reference beta source 77116. Spex Industries - certified solutions for all elements analyzed by atomic absorption or plasma-emission analysis. NBS standard reference materials - orchard leave, spinach, river sediments.

Quality Assurance - Interlaboratory Comparison Programs

The interlaboratory comparison programs in which SRC participated include:

> US EPA, Radiation Protection Bureau, Health and Welfare Canada, Ottawa; Air Pollution Technology Center, Environment Canada, Ottawa; Environment Canada; the Water Pollution Control Branch, Saskatchewan Environment, Regina; and CCRMP. The interlaboratory programs of significance to this project are:

- the CANMET Certified Reference Materials Program for the determination of Ra-226, Pb-210, Th-230, Po-210 and Ra-228 in ores and uranium tailings (CANMET Reports 83-9E, 83-112(TR), 78-22 and recent unpublished studies).
- USEPA
    - radium-226 and radium-228 in water
    - gross alpha and beta in water
    - uranium in water
    - iodine-131
    - gamma nuclides in water
    - gross alpha-gross beta, cesium-137 and strontium-90 on air filters
- Health and Welfare Canada, Radiation Protection Service
    - uranium in urine
- Environment Canada, Trace Metals in Water
    - in cooperation with Sask Environment

Quality Assurance - Laboratory QC Program

The laboratory Q.C. program is directed by the laboratory head and performed by the section supervisors (Lloyd MacDonald in radiochemistry, and Dr. Wo Yuen in general chemical analysis). All results are reviewed between the laboratory head and the section supervisors. Problems are analyzed and corrected on a daily basis.

Sample Identification and Recording Procedures: Upon receipt, samples were logged into the computer and given a group number. Then each sample was given a lab number and worksheets were printed out with proper analysis required. Samples were stored in a cool sample room until the analyst signed them out on the computer which records initials and date started. After removal from the cooler to begin analysis they are kept at room temperature until disposed of. Upon completion of analysis, samples were stored for 30 working days before discarding unless otherwise notified. SRC does not have sufficient cooler space to store all the current samples which are normally retained for six weeks.

Data Handling: All interlaboratory results and internal laboratory Q.C. results are stored in files and are not entered into the main computer data base because of problems that would occur with billing. These files contain all historical Q.C. data. When a client request Q.C. data, SRC must manually prepare a summary.

Instrument Calibration: All instruments are calibrated with each set of samples by analyzing a set of standards and blanks. Any change in the calibration curve results in readjustment of the instrument before analysis is continued. The low level radiation counters are checked against a calibrated source at the beginning of each week, or any time a change in counting efficiency is observed (i.e., when running standards).

Environmental Guidelines: The laboratory has a heating-air conditioning system which maintains room temperature at 24±1°C. SRC has experienced failure of the system on only two occasions in the past five years.

2.4.4 Results of Laboratory QA/QC program

The laboratory was requested to provide values of replicates and the measured values of reference standards. SRC was able to provide information on the known value of a reference standard and the measured value. These data are provided in Table 2.7 for the Gunnar field study. (The first number in each set of parenthesis is the known value of the analyzed standard. The second number is the result obtained). All results are pCi with the exception of Uranium which is ug/L for water and ug/g for solids.

TABLE 2.7: REFERENCE STANDARD VALUES AND MEASURED VALUES BY SRC

The first number in each set of parenthesis is the known value of the analyzed standard. The second number is the result obtained. All results are pCi, with the exception of uranium which is ug/L for water and ug/g for solids.

Gr. 84-1801 Jan.3/85 Rec'd Dec.13/84
Lab#12259-12265 Water

Pb210	(4.49, 4.7)
Po210	(4.49, 4.71)
Ra226	(120.4, 120.2);(12.04, 12.36)
Ra228	---
Th230	(50, 49.4)
U	(150, 152);(30, 32);(2000, 1900);(5000, 5200)

Gr. 85-12 Jan.17/85 Rec'd Jan.2/85
Lab#59-63 Soil

Pb210	(44.9, 49.4)
Po210	(44.9, 39.7)
Ra226	(1.20, 1.16);(120.4, 124.5)
Ra228	---
Th230	(3.6, 3.8)
U	(22, 20.5);(113, 107);(25, 25)

Gr. 85-84 Jan.28/85 Rec'd Jan.17/85
Lab#364-368 Water (Leach Tests) (Very small samples)

Pb210	(4.49, 3.88)
Po210	(4.49, 4.07)
Ra226	(60.2, 57.8);(1.20, 1.17)
Ra228	---
Th230	(50, 45.3)
U	(2, 2.4);(150, 156);(1000, 900)

Gr. 85-438 Apr.2/85 Rec'd Mar.25/85
Lab#2705-2710 Water

Pb210	(44.9, 42.9)
Po210	(44.9, 44.2)
Ra226	(6.02, 5.9);(120.4, 117)
U	(30, 34);(2000, 2100)

TABLE 2.7: REFERENCE STANDARD VALUES AND MEASURED VALUES BY SRC

Gr. 85-471 Apr.9/85 Rec'd Mar.29/85
Lab#2896-2903 Water

Pb210 (4.49, 4.67)
Po210 (4.49, 4.86)
Ra226 (12.04,11.6);(60.2, 58)
U (2.0, 2.2);(1000, 1000)

Gr. 85-138 Feb.1/85 Rec'd Jan.28/85
Lab#946-948 Soil

(One sample run 3 times; all "chemistry" analytes (plasma, leach tests etc)

Gr. 85-185 Feb.12/85 Rec'd Feb.6/85
Lab#1284

(Lab#947 repeat - Si)

Gr. 85-197 Feb.20/85 Rec'd Feb.8/85
Lab#1325-1329 Soil

Pb210 (4.49, 4.77)
Po210 (4.49, 4.78)
Ra226 (60.2, 56.8);(120.4, 122)
Ra228 ---
Th230 (3.6, 3.5)
U (39, 42);(53, 52)

Gr. 85-491 Apr.16/85 Rec'd Apr.2/85
Lab#2975-2986 Soil

Pb210 (4.49, 4.9)
Po210 (4.49, 4.2)
Ra226 (6.02, 6.0);(12.04, 11.8)
U (59, 59);(26.5, 25)

Gr. 85-490 Apr.22/85 Rec'd Apr.2/85
Lab#2971-2974 Water

Pb210 (4.49, 4.58)
Po210 (4.49, 5.0)
Ra226 (120.4, 124);(6.02, 5.8)
U (150, 140);(5000, 5150)

Gr. 85-570 Apr.25/85 Rec'd Apr.18/85
Lab#3435 Water

"chemistry" analytes only

TABLE 2.7: REFERENCE STANDARD VALUES AND MEASURED VALUES BY SRC

Gr. 85-853 June 18/85 Rec'd June 3/85
Lab#5735-5746 Solids

Pb210 (44.9, 42.2)
Po210 (44.9, 44.4)
Ra226 (60.2, 63);(120.4, 122)
U (97, 98);(375, 390)

Gr. 85-896 June 27/85 Rec'd June 7/85
Lab#6131-6139 Soil

Pb210 (44.9, 43.0)
Po210 (44.9, 43.2)
Ra226 (120, 116);(12.04, 11.1)
Th228 ---
Th230 (11.3, 11.5)
Th232 ---
U (60, 60);(106, 102)

Gr. 85-929 June 27/85 Rec'd June 12/85
Lab#6433-6436 Soil

Pb210 (44.9, 43.0)
Po210 (44.9, 43.2)
Ra226 (120.4, 116)
Th228 ---
Th230 (11.3, 11.9)
Th232 ---
U (21, 22);(149, 151)

Gr. 85-1050 July 17/85 Rec'd June 26/85
Lab#7665-7686 Water

U (2.0, 1.9);(150, 145);(1000, 1020)
Ra226 (on #7684, 85 and 86 only) (60.2, 57.5)

Gr. 85-1094 July 23/85 Rec'd July 4/85
Lab#8497 Soil

Pb210 ---
Po210 ---
Ra226 duplicate on analysis done: 544 pCi/g, 542 pCi/g
Th230 (15.4, 15.8)
U (1000, 996);(1730, 1710)

TABLE 2.7: REFERENCE STANDARD VALUES AND MEASURED VALUES BY SRC

Gr. 85-1179 Aug.13/85 Rec'd July 16/85
Lab#9126-9134 Soil

Pb210	(44.9, 42.1)
Ra226	(60.2, 57.6)
Ra228	---
Th228	---
Th230	(15.4, 15.3)
Th232	---
U	(149, 148);(439, 438)

Gr. 85-1718 Oct.10/85 Rec'd Sept.27/85
Lab#13112-13123 Water

Pb210	(4.33, 4.63)
Ra226	(12.04, 12.2) ; (6.02, 5.9)
Th228	---
Th230	(50, 50.9)
Th232	---
U	(30,34);(1000, 900)

Gr. 85-139 Feb.5/85 Rec'd Jan.28/85
Lab#949 Water (50 mls used for analysis)

Pb210	(44.9, 47.6)
Po210	---
Ra226	(120.4, 118)
Ra228	---
Th230	---
U	(30, 32)

Gr. 85-522 Apr.19/85 Rec'd Apr.9/85
Lab#3137-3142 Water (very small samples)

Ra226	(60.2, 61)
Ra228	---
Th228	---
Th230	---
Th232	---
U	(150, 146)

Gr. 85-1345 Aug.19/85 Rec'd Aug.7/85
Lab#10661-10665 Water

Ra226	(12.04, 12.2)
Pb210	(4.49, 4.6)
Th228	---
Th230	(50, 47.6)
Th232	---
U	(200, 191)

TABLE 2.7: REFERENCE STANDARD VALUES AND MEASURED VALUES BY SRC

```
Gr. 85-1373  Aug.28/85  Rec'd Aug.12/85
Lab#10743-10747  Water

      Pb210  ( 44.9, 42.1 )
      Ra226  ( 60.2, 61 )
      Ra228  ---
      Th230  ( 50, 52.1 )
      U      ( 150, 154 );( 1000, 950 )

Gr. 85-1374  Aug.28/85  Rec'd Aug.12/85
Lab#10748-10749  Soil

      Pb210  ( 4.49, 4.2 )
      Ra226  ( 60.2, 61 )
      Ra228  ---
      Th230  ( 15.4, 15.6 )
      U      ( 149, 151);( 1255, 1220 )
```

2.5 Chemex Laboratories (Chemex Labs Ltd.), Vancouver, B.C.

Chemex Laboratories were a check laboratory for analysis of radionuclides in synthetic water samples.

2.5.1 Laboratory Methods of Analysis (Chemex)

Sample Preservation and Preparation

Liquid Samples: It was assumed that any water samples for dissolved radionuclides were field-filtered and preserved prior to shipment to the laboratory. Any water samples for total radionuclides were also assumed to be acidified in the field; they were subsequently digested in the laboratory using hot concentrated nitric and perchloric acids prior to analysis.

Specific Analytical Procedures

(a) Pb-210

A tracer solution of stable lead and bismuth was added prior to digestion. Bismuth was then solvent-extracted and its recovery determined by atomic absorption spectrophotometry. Bismuth was then precipitated as bismuth oxychloride and beta-counted to measure Bi-210, the first daughter of Pb-210 and assumed to be in equilibrium with Pb-210 by virtue of its short half life. The detection limit for Pb-210 was 0.05 Bq. (CANMET, 1979).

(b) Po-210

An aliquot of the sample digest solution is reduced with ascorbic acid, heated to 90^{o} C and polonium-210 is allowed to deposit spontaneously onto a silver disc. The disc is then alpha-counted to determine Po-210 activity. The absolute detection limit for Po-210 is 0.01 Bq. (CANMET, 1979).

(c) Ra-226

A tracer solution of Ba-133 was added prior to digestion. Radium was subsequently dissolved, separated, purified and co-precipitated with $BaSO_4$. The overall chemical yield was determined by gamma counting of Ba-133; Ra-226 was then determined by alpha spectroscopy. The detection limit for Ra-226 is 0.01 Bq. (CANMET, 1979).

(d) Ra-228

Radium-228 and other radium isotopes were separated by co-precipitation with lead sulphate, re-dissolved and purified by co-precipitation with barium sulphate. The barium (radium) sulphate was stored to allow the ingrowth of Ac-228, the first daughter of Ra-228 and known to grow into equilibrium with Ra-228 by virtue of its short half life. Actinium-228 was then extracted from the precipitate, purified by solvent extraction and co-precipitated with lanthanum oxalate. The lanthanum (actinium) oxalate was then beta-counted to an absolute detection limit of 0.05 Bq. (CANMET, 1979).

(e) Thorium Isotopes

- Th-230

A tracer solution of Th-234 was added prior to digestion, as well as lanthanum chloride carrier and barium nitrate holdback carrier for radium. Thorium was co-precipitated with lanthanum hydroxide, purified and co-precipitated with lanthanum fluoride. The thorium precipitate was than beta-counted for Th-234 to measure the overall yield and then Th-230 is determined by alpha spectroscopy. The detection limit for Th-230 is 0.02 Bq. (CANMET, 1978).

- Th-232

Thorium-232 was determined by three different methods, alpha spectroscopy, gamma spectroscopy (neutron activation analysis) and colorimetry. The alpha spectroscopy procedure is as outlined for Th-230. The gamma spectroscopy procedure is conventional neutron activation analysis in which the gamma ray activity of the daughter product, Pa-233, is compared to the activity of standard reference materials. The determination of Th-232 by colorimetry as performed using arsenazo III following separation and purification of Th-232 by solvent extraction. (Talanta, 1961).

Porewater samples high in ferrous iron were treated by ion exchange techniques to remove iron and uranium in order to produce better quality alpha spectra. Sample aliquots were digested with aqua regia to oxidize iron to the ferric state. Sample residues were then dissolved in 9M hydrochloric acid and added to a column of anion exchange resin (chloride form). Iron and uranium, which form anionic chloro-complexes are strongly adsorbed whereas thorium, which does not form anionic chloro-complexes, passes through. Th-232 was routinely determined by colorimetry and samples with elevated activity were cross-checked by either gamma spectroscopy or alpha spectroscopy. (Palei, 1970).

- Th-228

Thorium-228 was determined by both alpha spectroscopy and gamma spectroscopy. The alpha spectroscopy procedure is as described above for Th-230. The gamma spectroscopy procedure involved the direct measurement of Th-228 by measurement of its gamma ray at 238 keV in comparison with standard reference materials.

(f) Total Uranium

Natural uranium was determined fluorimetrically as its fluoride complex following extraction into methyl isobutyl ketone from an acid-deficient aluminum nitrate solution. The detection limit for uranium was 0.1 ug. (ASTM, 1982, Vol. 31, Method D2907B).

2.5.2 Quality Assurance/Control Program (Chemex)

The Chemex quality assurance program consists of the analysis of primary and secondary reference materials, the replicate analysis of samples, frequent measurement cross-calibration, participation in interlaboratory control programs and the use of control charts for instrumental calibration. Laboratory technicians review data initially and perform check analyses if appropriate. Analytical data are then reviewed by the quality assurance coordinator before final certificates are generated.

Laboratory Quality Control Program

Reference Materials: Certified reference materials were routinely analyzed with each batch of twenty samples. Reference materials were analyzed wherever feasible, but in-house reference materials prepared internally, were also available for use in order not to deplete supplies of certified reference materials. For the analysis of surface waters, aliquots of NBS-traceable standard radionuclide solutions were analyzed with each batch of 10 samples since there are no standard reference materials available for samples of these types. Results of the data for reference materials are indicated in Section 2.5.3 and Table 2.10.

Measurement Cross-Calibration: Many elements can be determined by several different techniques. This permits systematic cross-checking to ensure the validity of data. Table 2.8(a) lists the variety of techniques available for some of the more important elements required for this project. Results are presented in Section 2.5.3 and Table 2.10.

Routine Quality Control Procedures: Routine Quality Control procedures involve sample storage, analysis of blanks, use of carriers and radiotracers, instrument calibration, duplicate analysis, and data reporting.

(i) Sample Storage: Porewater samples were filtered and preserved in the field. In the laboratory, the samples were stored at 4°C. Bottles were opened as infrequently as possible to minimize the oxidation of the high concentrations of ferrous iron. Multiple withdrawals of sample aliquots were made whenever bottles were opened.

TABLE 2.8a: ANALYTICAL TECHNIQUES (CHEMEX LABS)

Element	Analytical Technique
Ra-226	Gross Alpha, Alpha Spectroscopy, Gamma Spectroscopy
Pb-210	Beta Counting, Gamma Spectroscopy
Th-232	Alpha Spectroscopy, NAA, Colorimetry, ICP (total Th)
U	NAA (delayed neutron counting), NAA (gamma spectroscopy), fluorimetry, volumetric
Th-228	Alpha Spectroscopy, Gamma Spectroscopy

Key: NAA = Neutron Activation Analysis
AAS = Atomic Absorption Spectroscopy
ICP = Inductively Coupled Plasma Emission Spectroscopy

TABLE 2.8b: ESTIMATES OF PRECISION (95% Confidence Interval)

Element	Solutions (%)
Uranium-238	10
Thorium-232, -228	15
Thorium-230	20
Radium-226, -228	15
Lead-210	15
Polonium-210	15

(ii) Analysis of Blanks: Reagent blanks, procedural blanks and filter blanks were analyzed with each batch of samples and corrections made if appropriate.

(iii) Carriers and Radiotracers: The use of carriers and radiotracers were used to determine overall chemical yields for procedures including Ra-226, Pb-210 and Th isotopes.

(iv) Instrument Calibration: Control charts are maintained to monitor the alpha and beta backgrounds of counting equipment and also to monitor the efficiencies of standard alpha (Am-241) and beta (Cs-137) sources. The alpha spectroscopy system has been calibrated using NBS-traceable alpha sources including Gd-148, Am-241, Ra-226, Rn-222, Po-218 and Po-214 which cover an energy range of 3.18 to 7.69 MeV.

(v) Duplicate Analyses: Duplicate analyses were performed for each batch of samples provided that the availability of sample material permitted. Dustfall and hi-vol filters were not analyzed in this way because of the small sample weights available. Table 2.10 presents typical data obtained by the duplicate analyses of several batches of porewaters.

(vi) Data Reporting: All data entering the Chemex Labs database were verified by double data entry. The data were initially entered by one data entry operator and then independently confirmed by a second data entry operator. If the two sets of data did not match exactly, any entry discrepancies were immediately listed by the computer and corrected.

Accuracy and Precision

For the radionuclides analyzed as part of this project, the accuracy of the analyses may be assessed by an examination of the data presented for reference materials in Table 2.10(a). The precision of the data is estimated to be within the confidence intervals given in Table 2.8(b). These "confidence limit" estimates are based upon the participation by Chemex in various interlaboratory audits as well as on the reproducibility of replicate analysis.

Interlaboratory Audits

Chemex participates in numerous interlaboratory testing programs sponsored by government agencies. For radionuclide analysis, the most useful exchange program is the

Canadian Certified Reference Materials Project (CCRMP) sponsored by CANMET. The participation by Chemex for uranium ores and tailings and the various radionuclides is summarized in Table 2.9.

2.5.3 Results of Quality Assurance Program (Chemex).

Results of the Quality Assurance Program are given in Table 2.10 under the following headings:

2.10(a)	Analytical Data for Reference Material
2.10(b)	Measurement Cross Calibration Data
2.10(c)	Internal Replicate Analysis (Duplication) Data

Reference Materials

A comparison of measured concentrations in reference materials with the certified value is given in Table 2.10(a). The values found are generally within 1-2%.

Measurement Cross-Calibration

Table 2.10(b) presents analytical data for a number of different elements analyzed in porewaters as part of the measurement cross-calibration program of Lacnor.

Duplicate Analysis

Duplicate analysis is the splitting of a sample by the laboratory and the analytical measurement of each subsample. Sample results of duplicate analysis are given in Table 2.10(c).

TABLE 2.9: CHEMEX PARTICIPATION IN CCRMP

CCRMP Reference Material	Major Elements Certified
UTS-1, UTS-2, UTS-3, UTS-4	U, Th-230, Pb-210, Po-210, Fe, Al, Ti
DL-1a, DH-1a, BL-4a, BL-5	Pb-210, Ra-226
BL-5	U
DL-1a	U, Th
DH-1a	U, Th
CLV-1, CLV-2	Pb-210, Po-210, Ra-226, Th-230, U
RGU-1	U
RL-1	U
Fish Meal, Fish Bone	U, Pb-210, Po-210, Ra-226, Th-230

TABLE 2.10a: ANALYTICAL DATA FOR REFERENCE MATERIALS (CHEMEX)

Tailings Porewaters

Aliquots of NBS-traceable standard radionuclide solutions were analyzed with each batch of ten samples. Radionuclides analyzed in this fashion included Ra-226, Pb-210, Th-230, Th-228 and Th-232. Typical results are presented below:

Porewaters: **Chemex No. A8513090**

Isotope	Bq Added	Bq Found
Th-230	0.62	0.61
Th-232	0.41	0.37
Th-228	0.41	0.37

TABLE 2.10b: RESULTS OF MEASUREMENT CROSS CALIBRATION (CHEMEX)

Tailings Porewaters: **Chemex No. A8513090.** Typical results are:

Parameter: Th-232 (Bq/L)

Sample	Colorimetry	Gamma Spectroscopy
GW-01/E	5.2	5.9
GW-02/V	40.9	38.5
GW-02/VI	45.2	41.0
GW-02/VII	33.1	28.9

Parameter: Ra-226 (Bq/L)

Sample	Alpha Spectroscopy	Gross Alpha Counting
GW-02/IV	18.1, 19.3	18.7
GW-04/E	3.49	3.27
GW-04/F	3.06	2.99
GW-05/D	4.27	4.49
GW-05/K	3.39	3.31

TABLE 2.10c: DUPLICATE ANALYSES (CHEMEX)

Chemex No. A8513090

		U (ppm)	
Sample No.	Analysis #1	Analysis #2	Reported
GW-02/C	2,800	2,800	2,800
GW-04/C	435	465	450
GW-04/E	195	205	200

		Th-230 (Bq/L)	
Sample No.	Analysis #1	Analysis #2	Reported
GW-02/V	321	339	330
GW-02/VI	475	485	480

2.6 X-Ray Laboratories Limited, Don Mills, Ontario

2.6.1 Laboratory Methods of Analysis and Detection Limits

The laboratory method of analysis and detection limits are shown in Table 2.11.

TABLE 2.11: RARE EARTHS: METHODS OF ANALYSIS AND DETECTION LIMITS

Symbol	Element	Method*	Detection Limit (ppm)
Y	Yttrium	DCP	1.000
La	Lanthanium	NA	0.100
Ce	Cerium	NA	1.000
Pr	Praseodynmium	DCP	2.000
Nd	Neodymium	NA	3.000
Sm	Samarium	NA	0.010
Eu	Europium	NA	0.050
Gd	Gadolinium	DCP	2.000
Tb	Terbium	NA	0.100
Ho	Holmium	DCP	2.000
Er	Erbium	DCP	0.500
Tm	Thulium	DCP	0.500
Yb	Ytterbium	NA	0.050
Lu	Lutetium	NA	0.010

* DCP - Direct Current Plasma (DCP) Analyser

NA - Neutron Activation

2.7 Further Analyses of QA/QC Program

As indicated at the beginning of the appendix, **quality assurance** involves a total program for assuring the reliability of monitoring data. Quality control is the routine application of procedures for controlling the measurement process. For this study, quality assurance has involved several aspects including:

- correct sampling and field preservation techniques,
- analysis of sequential field samples,
- submission of duplicate samples submitted "blind" to the same laboratory,
- submission of duplicate samples to two different laboratories (the primary laboratory and a check laboratory),
- selection of reputable laboratories with a proven track record of analysis whose rate structure was economical,
- laboratory QA/QC procedures,
- checks on the analytical results such as:
  - cation-anion balance,
  - correlations between radionuclides and elemental analysis (e.g., total Th to Th-232; Pb210-stable Pb),
  - consistency of data with each other and expected geochemical behaviour.

As a result of the program, several discrepancies were obvious early. Others became apparent later in the program. These discrepancies resulted mainly from the interlaboratory audit (analysis of duplicate samples by two different programs). This led to submission of samples with known composition to the laboratories for analysis. The composition was essentially a calcium-iron-sulphate matrix containing Ra-226 and Th-230. A more detailed description of this program is given below (Section 2.7.3).

In this section, a qualitative picture of the quality assurance results are given and then the results of the QA audit with known samples are given.

2.7.1 Qualitative Description of QA/QC Results

The focus of the analytical effort was the tailings porewater. This particular component was chosen to receive a major portion of the quality control and quality assurance effort because of a series of factors including: (1) accessibility of the sample locations on a year round basis so that one particular location could be repeatedly sampled over the duration of the program, (2) the tailings porewater contains the highest mobile inventory of both radionuclides and trace elements and is the most important component (in conjunction with the solids) for assessing long-term environmental significance, and (3) the tailings porewater contains relatively high levels of substances such as calcium, sulphate and iron which are known to interfere with analyses of certain elements and cause sample changes in the field, and thus should result in the highest levels of sampling and analytical variability.

The tailings porewater was sampled on every field trip to establish the temporal variability of parameters in a relatively stable area. This would allow the opportunity to calculate an overall variance for this type of data. Samples were also collected from the same hole sequentially during the same sampling program in order to determine the range of variability associated with sequential sampling from the same location and at the same time.

For tailings porewater, surface water, atmospheric solids, tailings solids, and vegetation components, other measurements of quality assurance occurred. Samples were collected, mixed, and then split between laboratories to determine the range of interlaboratory variability or accuracy. Samples were collected and split so that blind replicates could be submitted to the same laboratory based upon separate batches in order to ascertain the degree of laboratory precision. Lastly, the laboratories replicated samples themselves in order to determine the degree of precision for various analyses as part of their own internal quality control program.

These data are all presented on the data tables in the various technical appendices. The reader should interpret these as the use of the data dictates. These quality control analyses including all of the above categories amounted to about 20 - 30 percent of the total analyses undertaken. In addition to these quality control cross checks, the data were also scrutinized to determine its reasonableness. For analysis of aqueous samples, which involved major cations and anions, a calculation of an electroneutrality balance was made. In cases where the data was unacceptable, a check was requested. The corrected data are presented on the data sheets included in the appendices to this report. In some cases, repeat analyses and calculation checks still resulted in an unsatisfactory balance. The cause of the imbalance remains unsolved. This, however, applies to only a small percentage of the samples.

In some instances, discrepancies in data reported for blind replicates between laboratories were traced to inconsistencies in reporting format. This has been noted and corrected in the data tables. In other cases, principally in the trace element analyses, certain pieces of data appear to be outliers. Values like these are left in the data set because they are the 'best' data available but it is recommended that these outliers be accounted for, if the data are to be used for modelling or other quantitative purposes.

In other instances, such as for stable lead, there is a consistent difference in the data between the check laboratory test and the main laboratory. These data are internally consistent as the blind replicates and internal quality control and assurance data shows, and are presented in the data table as reported after query by the project team. As the discrepancies for a couple of trace elements could not be resolved during the course of the program, a set of certified standards blended into a tailings porewater matrix were sent to each of the laboratories for analyses. These data are discussed below and should be used when interpreting the main body of data.

In general, for the types of analyses carried out in this study, given the types of matrices necessary to analyze in, the uncertainty associated with the major anions and cations is in the order of 30 percent at levels up into the parts per million or low parts per thousand levels. At the low parts per billion range the uncertainty is much larger being generally in the order of 2 to 5 times. The radionuclide analyses generally showed what would be considered to be relatively moderate levels in porewater for uranium mine tailings. The overall uncertainty associated with the analyses is judged to be on the order of 100 percent at or near the 1 Bq/L level, although the precision within a given laboratory on a split sample or blind replicate was better than this. At lower levels, nearing the detection limits for the radionuclide concerned, the overall accuracy was less.

The data necessary for a statistical evaluation of the accuracy and precision are available in the appendix documents, but no statistical analyses have been carried out under the terms of reference of this study. Any statistical analysis of the data set should be carefully planned in order to derive the type of data necessary for future use of this information. In the above section, an outline of all the analytical and quality control procedures followed by the various laboratories participating in the study along with the routine detection limits that the laboratories claim to be achievable in clear solutions are given. These detection limits are not necessarily valid for the matrix of the runoff waters analyzed in this project. The results from the next section should be used to critique the effect of the matrix.

2.7.2 Synopsis of Quality Assurance Results

A summary of internal laboratory quality results has been given above in the form of comparing laboratory measurement of reference samples with "certified" values. Representative results of the interlaboratory comparison involving measurement of the same sample by different laboratories or sequential samples are composited into one summary table. The table basically examines analytical measurements of tailings solids and tailings porewater for the Gunnar Tailings Management area because this geomorphological entity is the main area controlling the release of contaminants to aquatic and atmospheric pathways. Other quality assurance results are given in the appropriate sections.

2.7.3 Results of QA Audit

Samples of a known composition were submitted to Monenco, Chemex and SRC for radionuclide analysis, and to Barringer, BEAK and SRC for non-radionuclide analysis. Analytical results for radionuclides are given in Table 2.11(a) and for non-radionuclides in Table 2.11(b). The "known" concentrations of the samples are given in Table 2.11(c)(i). An estimate of the levels of other parameters is given in Table 2.11(c)(ii). The chemicals used to prepare the stock solutions are given in Table 2.11(d).

The master samples for radionuclide analysis were numbers 7, 9, and 10. The iron (II) sulphate, and calcium sulphate matrix was made up to emulate the porewater composition of the Lacnor tailings management area. Samples 1 to 3 were formed by

TABLE 2.12: INTERLABORATORY COMPARISON FOR GUNNAR PROJECT

Parent Material		Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Clay, medium plastic, light grey	Sand, silty reddish brown tailings
Field Code		NIC (alternate lab blind replicate)	NIC (blind field sequenced)	NIC (alternate lab blind replicate)	NIC (alternate lab blind replicate)	NIC (alternate lab blind replicate)	N5A (alternate lab blind replicate)	GM3C (alternate lab blind replicate)
Date		84.12.10	84.12.10	85.03.10	85.06.20/24	85.08.24	85.06.20/24	85.03.30
A. Interlaboratory Comparison for Non-Radioactive Substances (BEAK as prime lab; SRC as check lab)								
Parameter								
pH:	L	7.8	-	6.9 (7.99)	6.8 (8.03)	7.4 (7.97)	7.8 (8.28)	6.7 (6.76)
	F	6.88	-	-	-	-	-	-
Acidity ($CaCO_3$) (mg/L)		-	-	180 (201)	144 (27)	- (L 1)	10	170/160
Alkalinity ($CaCO_3$) (mg/L):	L	565/610	-	840	570 (646)	570 (563)	180/190 (217)	380/370 (386)
	F	767	-	-	-	-	-	-
Conductivity (umhos/cm^2):	L	5,600	-	5,800 (5,550)	5,000	5,900/5,800 (5,760)	600	4,300/4,260
	F	5,500	-	-	-	-	.	-
Total Dissolved Solids (105°C) (mg/L)		5,500	-	6,000 (5,880)	6,000 (6,400)	- (1,370)	330 (440)	4,200/4,200
DOC (mg/L)		680	-	14 (12)	7.5 (L 1)	8 (3)	11.0 (23)	37 (22)
DIC (mg/L)		480	-	150 (46)	110 (170)	161/151 (160)	34 (49)	30 (98)
Kjeldahl-N (mg/L)		-	-	1.68	2.40	-	1.26	-
Major Anions (mg/L):								
Bromide		L 1	-	0.1	-	0.4 (0.15)	0.3/0.3 (0.05)	0.5 (1.0)
Chloride		220/220	-	330 (320)	270/280 (339)	300 (313)	18 (25)	180 (211)
Fluoride		1.6	-	1.0/0.7	0.6/0.7 (0.86)	1.4 (0.86)	0.3/0.3 (0.47)	1.1 (2.0)
Sulphate		2,700	-	3,300 (3,420)	3,100/3,200 (3,430)	3,300 (3,350)	115/116 (110)	2,700 (2,570)
Nitrate		1	-	L 0.2	-	1.4	L 0.2	L 1 (0.32)
Major Cations (mg/L):								
Magnesium		550 (640)	680	720 (740)	660//640 (672)	719 (710)	28//30 (35)	430 (460)
Calcium		420/410 (630)	590/480	520 (530)	480//430 (516)	500/500 (409)	69//69 (74)	530 (540)
Iron		123 (120)	157/132	69 (59)	44/43 (34)	40 (34)	0.03 (0.30)	24/26 (16)
Manganese		36 (420)	37	47 (38)	41 (34)	40 (44)	0.87 (1.1)	17.0 (14)
Silica SiO_2		36	48	50/49 (26)	46/51 (26)	- (2.6)	26 (2.6)	41 (0.2)
Aluminum		0.29 (1.0)	0.33	0.45 (0.05)	1.1//0.81 (0.01)	0.81 (0.017)	0.16//0.15 (0.008)	0.73 (0.03)
Sodium		156/140 (130)	185/175	200 (210)	197//196 (198)	192/176 (202)	23//23 (24)	130 (140)
Potassium		20/17 (17)	24/22	19.1 (14)	16//17.0 (16)	17.1/15.6 (16)	3.8//3.8 (3.5)	6.9 (4.0)
Trace Cations (mg/L):								
Strontium		1.80	2.4	2.5 (2.1)	2//2.7 (1.6)	2.6 (2.1)	0.42//0.44 (0.31)	1.56 (0.86)
Lead		0.20 (0.06)	0.66	0.24/0.20 (L 0.005)	0.33 (L 0.005)	0.55 (0.003)	0.01 (L 0.005)	0.28 (L 0.005)
Cobalt		0.05 (0.021)	0.14	0.11/0.10 (0.20)	0.16 (0.014)	0.24 (0.024)	L 0.01 (0.001)	0.13 (0.011)
Nickel		0.04 (0.033)	0.12	0.07/0.07 (0.034)	0.05 (0.083)	0.065 (0.024)	0.01 (0.011)	0.04 (0.007)
Zinc		0.160 (0.10)	0.200	0.170 (0.036)	0.110 (0.18)	0.090 (0.016)	0.015 (0.014)	0.100 (0.004)

TABLE 2.12: INTERLABORATORY COMPARISON FOR GUNNAR PROJECT

Parent Material	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Clay, medium plastic, light grey	Sand, silty reddish brown tailings
Field Code	NIC (alternate lab blind replicate)	NIC (blind field sequenced)	NIC (alternate lab blind replicate)	NIC (alternate lab blind replicate)	NIC (alternate lab blind replicate)	N5A (alternate lab blind replicate)	GM3C (alternate lab blind replicate)
Date	84.12.10	84.12.10	85.03.10	85.06.20/24	85.08.24	85.06.20/24	85.03.30
Chromium	0.01 (0.035)	0.06	0.04/0.04 (0.024)	0.04 (0.072)	0.050 (0.036)	L 0.01 (L 0.001)	0.04 (0.013)
Copper	0.010 (0.003)	0.025	0.030/0.030 (0.038)	0.020 (0.009)	0.020 (0.003)	0.005 (0.020)	0.030 (0.012)
Cadmium	0.015 (L 0.001)	0.050	0.050 (0.003)	0.025 (L 0.001)	0.030 (L 0.001)	0.01 (L 0.001)	0.030 (L 0.001)
Barium	0.06 (0.12)	0.07	0.02 (0.069)	L 0.05//0.04 (0.017)	0.030 (0.012)	0.08//0.08 (0.073)	L 0.01 (0.037)
Vanadium	0.02 (0.13)	0.03	0.03 (0.11)	L 0.05//0.04 (0.09)	0.040 (0.15)	L 0.01//L 0.01 (0.01)	0.03 (0.10)
Titanium	0.30 (0.01)	0.36	0.32 (0.006)	- (L 0.001)	- (L 0.001)	- (L 0.001)	0.46 (0.004)
Arsenic (ug/L)	64	64	72/66 (110)	-	-	-	112 (80)
Selenium (ug/L)	L 0.5	L 0.5	-	-	-	-	-
Molybdenum	0.08 (0.08)	0.09	0.08 (0.05)	0.2//0.13 (0.01)	0.14 (0.078)	0.03//0.03 (0.006)	0.14 (0.03)
Beryllium	L 0.01 (0.023)	L 0.01	L 0.01 (0.008)	L 0.05//L 0.01 (0.004)	L 0.01 (0.005)	L 0.01//L 0.01 (L 0.001)	L 0.01 (0.002)
Sum Anions	74.1 (-)	-	94.8 (100.8)	83.5 (93.8)	88.5 (89.8)	6.60 (7.33)	68.8 (67.1)
Sum Cations	72.8 (90.1)	(91.0)	97.9 (97.0)	90.1 (90.6)	92.5 (88.0)	7.04 (7.70)	71.0 (74.2)
Tritium (T.U.)	-	-	-	-	-	-	-
B. Interlaboratory Comparison for SRC (Monenco) for Radionuclides							
Uranium (ug/L)	2,300/2,600*	2,600	8,000 (7,400)	8,400	8,300 (8,300)	25±4	11,500 (13,500/14,000)
Thorium-230 (Bq/L)	0.16/1.7*	0.75	-	-	0.03 (0.04±0.01)	-	0.119±0.006 (0.063±0.005)
Radium-226 (Bq/L)	2.1/4.5*	2.6	3.0 (2.44±0.12)	3.0	2.5 (1.95±0.10)	1.2	1.9 (2.94±0.04/ 3.05±0.06)
Lead-210 (Bq/L)	L 0.3/1.5*	2.3	1.5 (2.75±0.15)	0.9	5.0 (1.1±0.1)	L 0.02	3.0 (2.43±0.23/ 5.34±0.43)
Polonium-210 (Bq/L)	0.4/0.26*	1.4	0.25 (1.35±0.04)	-	-	-	0.02 (0.408±0.076/ 1.23±0.21)
Radium-228 (Bq/L)	L 0.1/0.25*	L 0.1	-	-	-	-	-
Thorium-232 (Bq/L)	-	-	-	-	L 0.02	-	-
Thorium-228 (Bq/L)	-	-	-	-	L 0.02	-	-

L = Less than.
( ) Alternate lab blind replicate.
* Blind replicate.

	Surface flow in small creek approx. 3 L/s WRS (alternate lab blind replicate)
Date	85.06.20/24
	7.8 (8.3)
	-
	4
	107 (116)
	-
	1,380
	-
	1,380 (1,580)
	14.0 (16)
	17.0 (25)
	0.35
	L 0.5 (0.20)
	20 (14)
	0.5 (0.78)
	770 (930)
	L 0.5
	29//59 (70)
	99//290 (298)
	0.27 (0.34)
	0.20 (0.25)
	13.7 (7.5)
	0.72//0.96 (0.65)
	12.0//25 (43)
	1.52//2.4 (2.3)
	0.25//0.67 (0.47)
	0.06 (L 0.005)
	0.02 (0.002)
	0.01 (0.008)
	0.015 (0.049)

	Surface flow in small creek approx. 3 L/s
Field Code	WRS (alternate lab blind replicate)
Date	85.06.20/24
	L 0.01 (0.002)
	0.015 (0.031)
	L 0.005 (L 0.001)
	0.03//0.04 (0.058)
	0.01//0.02 (0.01)
	-
	-
	-
	0.04//0.08 (0.006)
	0.01//L 0.01 (L 0.001)
	18.7 (22.1)
	20.5 (22.3)
	-
	2,000
	-
	1.1
	0.05
	-
	-
	-
	-

dilution of samples 7, 9 and 10 by two-, eight- and ten-fold respectively. These samples were formed to emulate surface waters and were analyzed only for non-radionuclide parameters. The following are duplicates: sample 1 and 4; samples 2 and 6, samples 3 and 5; and samples 7 and 8.

The synthetic samples 7, 9, and 10 for radionuclide analysis were prepared by CANMET Laboratories and submitted directly by CANMET under a covering letter from the project team. The synthetic samples 1-6 were also diluted by CANMET and submitted for analysis. The Fe, Ca, K, SO_4 contents of the synthetic samples 7-10 for non-radionuclide analyses were prepared by CANMET. The contents for Al, Ba, Cd, Co, Cr, Pb were prepared by BEAK and added into the samples prepared by CANMET, and then submitted to the laboratories.

The results of the radionuclides analyses indicate that the ratio of the measured values to known values ranges within 0.8 to 1.2 (the expected ratio) for all samples and laboratories except for the thorium-230 analyses by Chemex for the sample having the lowest thorium-230 content. The cause of this is not understood at this time.

The results for the non-radionuclide parameters given in Table 2.11(b) show general agreement with the known values. It is left to the readers to make an assessment of the degree of agreement which is desired for their particular purpose. A few points are in order for the trace constituents.

(i) For many of the trace constituents, a small concentration is measured by all laboratories. It is difficult to assess what should be a proper "zero" concentration because of the trace metal level in the distilled water used to prepare the samples is not known.

(ii) The laboratories show general agreement with known values for the addition of trace metals. This data can then be used to assess the capability of DCP and ICP to measure concentrations of Al, Ba etc. in the 0.1 to 1.0 mg/L range on the presence of a calcium - iron matrix. There is one exception: the Barringer analysis for Pb is low, suggesting that their correction for a calcium interference for Pb is excessive.

TABLE 2.11(a)(i) VALUES OF RADIONUCLIDE PARAMETERS MEASURED BY LABORATORIES

Parameter	Sample No.	Known Value	Monenco		SRC		Chemex	
Ra-226	1	2.8	2.51	2.94	2.9	2.8	2.3	2.4
	2	10.6	9.0	9.0	10	11	8.7	9.3
	3	1.17	1.18	1.08	1.3	1.2	0.97	0.93
Th-230	1	0.58	0.47	0.47	0.6	0.55	2.2	1.9
	2	5.82	4.6	4.1	8	6	7.7	7.2
	3	0.80	0.62	0.42	0.7	0.8	1.1	1.0

TABLE 2.11(a)(ii) RATIO OF MEASURED VALUE TO KNOWN VALUE

Parameter	Sample No.	Known Value	Monenco		SRC		Chemex	
Ra-226	1	1.	0.90	1.05	1.04	1.0	0.82	0.86
	2	1.	0.85	0.85	.94	1.04	0.82	0.88
	3	1.	1.01	0.92	1.11	1.03	0.83	0.79
Th-230	1	1.	0.81	0.81	1.03	0.95	3.8	3.3
	2	1.	0.79	0.70	1.37	1.0	1.3	1.24
	3	1.	0.78	0.50	0.88	1.0	1.38	1.25

TABLE 2.11(b)(i)

MEASUREMENT OF KNOWNS BY BARRINGER MAGENTA

Parameter	Sample 1	Sample 4 (Dupl. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7++	Sample 8++ (Dupl. of Sample 7) *	Sample 9++	Sample 10++
Ag (mg/L)	L .005	L .005	L .005	L .005	L .005	L .005	L .005	L .005	L .005	L .005
Al (mg/L)	L .01	L .01	.05	L .01	L .01	L .01	2.56 $^{(2)}$	.65 $^{(.2)}$	2.44 $^{(2.)}$	2.22 $^{(2.)}$
B (mg/L)	L .004	.016	L .004	0.56	.043	.039	.607	.650	1.12	2.26
Ba (mg/L)	L .005	L .005	L .005	L .005	L .005	L .005	.184 $^{(.2)}$	.018 $^{(.02)}$	.173 $^{(.2)}$	.166 $^{(.2)}$
Be (mg/L)	L .0005	L .0005	L .0005	L .0005	L .0005	L .0005	.0005	L .0005	.0021	.0016
Ca (mg/L)	175	177	63.4	60.1	42.7	44.2	331	344	459	426
Cd (mg/L)	L .01	L .01	L .01	L .01	L .01	L .01	.92 $^{(1.)}$	.10 $^{(.1)}$	.96 $^{(1.)}$	.92 $^{(1.)}$
Co (mg/L)	L .05	L .05	L .05	L .05	L .05	L .05	.80 $^{(1.)}$	L .05 $^{(.1)}$	.85 $^{(1.)}$	.59 $^{(1.)}$
Cr (mg/L)	.03	.03	.03	.03	.02	.02	.85 $^{(1.)}$	L .01 $^{(.1)}$	.68 $^{(1.)}$	.47 $^{(1.)}$
Cu (mg/L)	.017	.013	.012	.009	.008	.012	.040	.043	.104	.163
Fe (mg/L)	410	415	242	235	349	352	779	808	1820	3390
K (mg/L)	12	12	7	6	8	9	26	26	54	95
Mg (mg/L)	55.4	56.5	22.6	21.4	6.05	6.22	103	106	165	60.1
Mn (mg/L)	.52	.52	.34	.32	.47	.47	1.03	1.06	2.45	4.60
MO (mg/L)	.2	.3	L .2	L .2	L .2	L .2	1.5 $^{(1.)}$	1.0 $^{(.1)}$	2.4 $^{(1.)}$	6.2 $^{(1.)}$
Na (mg/L)	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	2	2
Ni (mg/L)	.06	.07	L .05	L .05	L .05	L .05	.11	.11	.20	.30
P (mg/L)	L .5	L .5	L .5	L .5	L .5	L .5	L .5	L .5	L .5	L .5
Pb (mg/L)	L .05	L .05	L .05	L .05	L .05	L .05	L .05 $^{(1.)}$	L .05 $^{(.1)}$	L .05 $^{(1.)}$	L .05 $^{(1.)}$
Si (mg/L)	.18	.18	.18	.18	.06	.06	.17	.19	.53	.24
Sr (mg/L)	.051	.050	.017	.016	.010	.011	.094	.095	.124	.116
Th (mg/L)	L .05	L .05	L .05	L .05	L .05	L .05	L .05	L .05	.42	.62
Ti (mg/L)	L .005	L .005	L .005	L .005	L .005	L .005	L .005	L .005	.040	.034
V (mg/L)	L .005	L .005	.010	L .005	L .005	L .005	L .005	.010	.056	.062
Zn (mg/L)	L .05	L .05	L .05	L .05	L .05	L .05	L .05	L .05	.06	.11
Zr (mg/L)	L .05	L .05	L .05	L .05	L .05	L .05	L .05	L .05	L .05	L .05
AN/CAT %	13.1	15.7	10.7	15.6	10.9	13.7				

TABLE 2.11(b)(i)

MEASUREMENT OF KNOWNS BY BARRINGER MAGENTA

Parameter	Sample 1	Sample 4 (Dupl. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7++	Sample 8++ (Dupl. of Sample 7) *	Sample 9++	Sample 10++
PH	1.90	1.89	2.31	2.30	1.91	1.90				
F- (mg/L)	.68	.68	.27	.27	.27	.27				
CL- (mg/L)	450	496	230	245	659	751				
NO2- (mg/L)	L .2	L .2	L .2	L .2	L .2	L .2				
PO4-3 (mg/L)	L .1	L .1	L .1	L .1	L .1	L .1				
BR- (mg/L)	L .5	L .5	L .5	L .5	L .5	L .5				
NO3- (mg/L)	L .5	L .5	L .5	L .5	L .5	L .5				
SO4= (mg/L)	2600	2730	884	959	996	1030				

Instrumentation: ICP: Ag to Zr; Ion Chromatography - F to SO_4^{2-}.

* Duplicate of Sample 7, except for Al, Ba, Cd, Co, Cr, Mo, Pb which were added in the amount indicated in brackets.

++ Al, Ba, Cd, Co, Cr, Mo, Pb added in amounts indicated in brackets.

TABLE 2.11(b)(ii)

MEASUREMENT OF KNOWNS BY BEAK ANALYTICAL SERVICES

Parameter	Sample 1	Sample 4 (Dupl. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7++	Sample 8++ (Dupl. of Sample 7) *	Sample 9++	Sample 10++
IC Scan: mg/L										
Fluoride	0.2/0.4	0.9	0.05	0.05	0.05	0.05				
Chloride	400	370	210	210	620/670	640				
Nitrite-N	L 3	L 3	L 1	L 3	L 3	L 3				
Ortho-Phosphate-P	L 0.5	L 0.5	L 0.5	L 0.5	L 0.5	L 0.5				
Nitrate-N	L 0.3	L 0.3	L 0.3	L 0.3	L 0.3	L 0.3				
Sulphate	2200	1920	760	760	800/760	750				
DCP Scan: mg/L										
Beryllium	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	0.010
Molybdenum	0.07	0.05	0.03	0.02	0.03	0.02	$1.01^{(1)}$	$0.21^{(.1)}$	$1.41^{(1)}$	$1.56^{(1)}$
Calcium	179	167	98	81	58	44	460	400	570	370
Vanadium	0.015	0.015	0.010	L 0.005	0.005	L 0.005	0.030	0.035	0.075	0.095
Aluminum	0.18	0.12	0.07	0.06	0.05	0.04	$1.88^{(2.0)}$	$0.46^{(.2)}$	$2.4^{(2)}$	$2.3^{(2)}$
Magnesium	67	55	27	25	7.8	6.5	107	121	220	76
Barium	0.02	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01	$0.20^{(.2)}$	$0.04^{(.02)}$	$0.30^{(.2)}$	$0.29^{(.2)}$
Potassium	14.5	15.3	8.1	8.0	13.2	11.7	29	30	57	89
Strontium	0.09	0.05	0.03	0.02	0.02	.01	0.11	0.13	0.21	0.20
Sodium	2.4	2.2	1.4	0.8	L 0.2	L 0.2	3.8	5.6	9.4	10.4
Zinc	0.040	0.040	0.010/0.005	0.020	0.030	0.030	0.06	0.06	0.130	0.125
Cadmium	0.125	0.135	0.055/0.070	0.080	0.110	0.115	$1.23^{(1)}$	$0.38^{(.1)}$	$1.63^{(1)}$	$1.96^{(1)}$
Manganese	0.52	0.50	0.29/0.30	0.29	0.43	0.43	1.03	1.05	2.5	4.3
Cobalt	0.04	0.05	0.02/0.02	0.030	0.03	0.05	$1.12^{(1)}$	$0.20^{(.1)}$	$1.22^{(1)}$	$1.16^{(1)}$
Copper	0.015	0.015	0.010/0.010	0.015	0.015	0.010	0.035	0.030	0.060	0.080
Silver	0.04	L 0.01	L 0.01/L 0.01	0.02	L 0.01	0.06	0.03	0.05	0.08	0.09
Iron	340	360	220	161	310	300/320	730	720	1570	3000
Lead	0.27	0.29	0.13/.12	0.17	0.13	0.31	$1.47^{(1)}$	$0.61^{(.1)}$	$2.1^{(1)}$	$2.0^{(1)}$

TABLE 2.11(b)(ii)

MEASUREMENT OF KNOWNS BY BEAK ANALYTICAL SERVICES

Parameter	Sample 1	Sample 4 (Dup. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7	Sample 8 (Dupl. of Sample 7) *	Sample 9++	Sample 10++
Chromium	0.030	0.030	0.015/0.010	0.020	0.010	0.040	$1.08^{(1)}$	$0.15^{(.1)}$	$1.10^{(1)}$	$1.03^{(1)}$
Nickel	0.06	0.06	0.04/0.04	0.04	0.04	0.07	0.12	0.13	0.29	0.42
Silica (SiO_2)	0.17	0.21	0.14	0.08	0.15	0.03	0.69	0.50	0.94	0.19
Titanium	0.14	0.14	0.06	0.05	0.05	0.05				

Measurement Instrumentation: Ion Chromatography: F, Cl, NO_2^-, NO_3^-, PO4, SO_4^{2-} ; others by DCP Scan.

* Duplicate of Sample 7, except for Al, Ba, Cd, Co, Cr, Mo, Pb which were added in the amount indicated in brackets.

++ Al, Ba, Cd, Co, Cr, Mo, Pb added in amounts indicated in brackets.

TABLE 2.11(b)(iii) MEASUREMENT OF KNOWNS BY SASKATCHEWAN RESEARCH COUNCIL

Parameter	Sample 1	Sample 4 (Dupl. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7++	Sample 8++ (Dupl. of Sample 7) *	Sample 9 ++	Sample 10++
Cl (mg/L)	410	420	190	200	670	670				
SO4 (mg/L)	1900	1900	700	700	760	780				
NO2 (mg/L)	Not Req	Not Req	Not Req	Not Req	Not Req	Not Req				
NO3 (mg/L)	Not Req	Not Req	Not Req	Not Req	Not Req	Not Req				
PO4 (mg/L)	Not Req	Not Req	Not Req	Not Req	Not Req	Not Req				
B (mg/L)	L 0.05*	L 0.05*	L 0.05*	L 0.05	L 0.05*	L 0.05	(L 0.05*)	(L 0.05*)	(L 0.05*)	(L 0.05*)
Br (mg/L)	Not Req	Not Req	Not Req	Not Req	Not Req	Not Req				
F (mg/L)	L 0.01	L 0.01	0.06	0.06	L 0.01	0.06				
P (mg/L)	(0.66*)	(0.75*)	(0.38*)	(0.36*)	(0.47*)	(0.52*)	(1.6*)	(1.5*)	(3.0*)	(4.7*)
Ag (mg/L)	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.005	L 0.005	L 0.005	L 0.005
Al (mg/L)	0.063	0.055	0.048	0.036	0.029	0.038	2.1 $^{(2.)}$	0.42 $^{(.2)}$	2.1 $^{(2.)}$	1.9 $^{(2.)}$
Ba (mg/L)	0.008	0.008	0.006	0.007	0.006	0.006	0.17 $^{(.2)}$	0.014 $^{(.02)}$	0.16 $^{(.2)}$	0.16 $^{(2.)}$
Be (mg/L)	0.058	0.059	0.038	0.036	0.055	0.055	0.10	0.10	0.23	0.42
Ca (mg/L)	210	200	69	69	51	52	350	360	480	440
Cd (mg/L)	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	1.0 $^{(1.)}$	0.096 $^{(.1)}$	1.0 $^{(1.)}$	1.0 $^{(1.)}$
Co (mg/L)	0.013	0.013	0.009	0.008	0.012	0.013	0.91 $^{(1.)}$	0.12 $^{(.1)}$	0.93 $^{(1.)}$	0.97 $^{(1.)}$
Cr (mg/L)	0.023	0.023	0.016	0.016	0.024	0.026	0.94 $^{(1.)}$	0.14 $^{(.1)}$	0.96 $^{(1.)}$	1.1 $^{(1.)}$
Cu (mg/L)	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.005	L 0.005	L 0.005	L 0.005
Fe (mg/L)	350	340	210	180	280	310	800	820	1900	3400
K (mg/L)	16	16	8.8	8.9	12	12	29	29	54	94
Mg (mg/L)	58	55	24	24	6.8	6.7	94	95	160	50
Mn (mg/L)	0.36	0.38	0.24	0.24	0.36	0.37	0.81	0.83	1.9	3.5
Mo (mg/L)	0.041	0.042	0.026	0.024	0.034	0.036	0.86 $^{(1.)}$	0.084 $^{(.1)}$	0.84 $^{(1.)}$	0.82 $^{(1.)}$
Na (mg/L)	0.2	0.2	0.2	L 0.2	L 0.2	L 0.2	0.35	0.41	0.66	0.27
Ni (mg/L)	0.029	0.035	0.020	0.023	0.029	0.032	0.078	0.066	0.17	0.34
Pb (mg/L)	0.11	0.10	0.084	0.069	0.090	0.090	1.1 $^{(1.)}$	0.27 $^{(.1)}$	1.4 $^{(1.)}$	1.8 $^{(1.)}$
Si (mg/L)	L 0.05	L 0.05	L 0.05	L 0.05	0.08	0.12	L 0.2	L 0.2	L 0.2	L 0.2

TABLE 2.11(b)(iii)

MEASUREMENT OF KNOWNS BY SASKATCHEWAN RESEARCH COUNCIL

Parameter	Sample 1	Sample 4 (Dupl. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7++	Sample 8++ (Dupl. of Sample 7) *	Sample 9 ++	Sample 10++
Ti (mg/L)	L 0.001	L 0.001	0.002	0.002	L 0.001	L 0.001	L 0.005	L 0.005	L 0.005	L 0.005
V (mg/L)	0.08	0.09	0.05	0.05	0.07	0.07	0.18	0.19	0.39	0.64
W (mg/L)	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.02	L 0.02	L 0.02	L 0.02
Zn (mg/L)	0.086	0.065	0.057	0.067	0.066	0.076	0.092	0.092	0.23	0.44

Not Req - SRC terminology which means "levels are too low to detect by ion chromatography".

Measurement Instrumentation: Cl - $AgNO_3$ titr.; SO_4: gravi; NO_2, NO3; PO4; Br- ion chromatography; F: fluoride electrode; others: ICP-AES.

* Parameters measured by ICP.

+ Duplicate of Sample 7, except for Al, Ba, Ca, Co, Cr, Mo, Pb which were added in the amount indicated in brackets.

++ Al, Ba, Ca, Co, Cr, Mo, Pb added in amounts indicated in brackets.

TABLE 2.11(b)(iv) COMPARISON OF MEASUREMENTS WITH KNOWN VALUES

		Concentration of Constituent (mg/L)			
Sample	Constituent	Known Value	Beak Measurement	Barringer Measurement	SRC Measurement
1, 4	Fe	400	340, 360	410, 415	350, 340
	Ca	180	179, 167	175, 177	210, 200
	Mg	63	67, 55	55, 57	67, 55
	K	15	15, 15	12, 12	16, 16
	SO_4^{2-}	1600	2200, 1920	2600, 2730	1900, 1900
2, 6	Fe	225	220, 161	242, 235	210, 180
	Ca	60	98, 81	63.4, 60.1	69, 69
	Mg	25	27, 25	22.6, 21.4	24, 24
	K	7.5	8.1, 8	7, 6	8.8, 8.9
	SO_4^{2-}	683	760, 760	884, 959	700, 700
3, 5	Fe	340	310, 300/320	349, 352	280, 310
	Ca	45	58, 44	42.7, 44.2	51, 52
	Mg	7	7.8, 6.5	6.05, 6.22	6.8, 6.7
	K	11	13.2, 11.7	8, 9	12, 12
	SO_4	761	800, 750	996, 1030	760, 780
7, 8	Fe	800	730, 720	779, 808	800, 820
	Ca	360	460, 400	331, 334	350, 360
	Mg	125	107, 121	103, 106	94, 95
	K	30	29, 30	26, 26	29, 29
7	Al	2	1.88	2.56	2.1
	Ba	.2	0.20	.184	.17
	Cd	1	1.23	.92	1.0
	Co	1	1.12	.80	0.91
	Cr	1	1.08	.85	0.94
	Mo	1	1.01	1.5	0.86
	Pb	1	1.47	L .05	1.1
8	Al	.2	.46	.65	.42
	Ba	.02	.04	.018	.014
	Cd	.1	.38	.1	.096
	Co	.1	.20	.05	.12
	Cr	.1	.15	L .01	.14
	Mo	.1	.21	1.	.084
	Pb	.1	.61	L .05	.27
9	Fe	1800	1570	1820	1900
	Ca	480	570	459	480
	Mg	200	220	165	160
	K	60	57	54	54
	Al	2.	2.4	2.44	2.1
	Ba	.2	0.30	.173	.16
	Cd	1.	1.63	.96	1.
	Co	1.	1.22	.85	.93
	Cr	1.	1.1	.68	.96
	Mo	1.	1.41	2.4	.84
	Pb	1.	2.1	L .05	1.4
10	Fe	3400	3000	3390	3400
	Ca	450	370	426	440
	Mg	70	76	60.1	50
	K	110	89	95	94
	Al	2.	2.3	2.22	1.9
	Ba	.2	.29	.166	.16
	Cd	1.	1.96	.92	1.
	Co	1.	1.16	.59	.97
	Cr	1.	1.03	.47	1.1
	Mo	1.	1.56	6.2	.82
	Pb	1.	2.0	L .05	1.8

TABLE 2.11(b)(v)

MEASUREMENT OF TRACE ELEMENTS IN SAMPLES WITHOUT TRACE ELEMENT ADDITION

	Sample 3, 5 (Sample 10; diluted 10-fold)			Sample 2, 6 (Sample 9; diluted 8-fold)			Sample 1, 4 (Sample 7, 8; diluted 2-fold)		
Parameter	Beak	Barringer	SRC	Beak	Barringer	SRC	Beak	Barringer	SRC
Al	.05, .04	L .01, L .01	.029, .038	.07, .06	.05, L .01	.048, .036	.18, .12	L .01, L .01	.063, .055
Ba	L .01, L .01	L .005, L .005	.006, .006	L .01, L .01	L .005, L .005	.006, .007	.02, L .01	L .005, L .005	.008, .008
Cd	.11, .115	L .01, L .01	L .001, L .001	.055, .080	L .01, L .01	L .001, L .001	.125, .135	L .01, L .01	L .001, L .001
Co	.03, .05	L .05, L .05	.013, .013	.02, .03	L .05, L .05	.009, .008	.04, .05	L .05, L .05	.013, .013
Cr	.01, .04	.02, .02	.024, .026	.015, .02	.02, .03	.016, .016	.03, .03	.03, .03	.023, .023
Mo	.03, .02	L .2, L .2	.034, .036	.03, .02	L .2, L .2	.026, .024	.07, .05	.2, .3	.041, .042
Pb	.13, .31	L .05, L .05	.090, .090	.13, .17	L .05, L .05	.084, .069	.27, .29	L .05, L .05	.11, .10

TABLE 2.11(b)(vi)

MEASUREMENT OF TRACE ELEMENTS ON SAMPLES WITH TRACE ELEMENT ADDITION

Parameter	Sample No. 7 (mg/L)				Sample No. 8 (mg/L)				Sample No. 9 (mg/L)				Sample No. 10 (mg/L)			
	Known Value	Beak	Barringer	SRC	Known Value	Beak	Barringer	SRC	Known Value	Beak	Barringer	SRC	Known Value	Beak	Barringer	SRC
Al	2	1.88	2.56	2.1	.2	.46	.65	.42	2.	2.4	2.44	2.1	2.	2.3	2.22	1.9
Ba	.2	0.20	.184	.17	.02	.04	.018	.014	.2	0.30	.173	.16	.2	.29	.166	.16
Cd	1	1.23	.92	1.0	.1	.38	.1	.096	1.	1.63	.96	1.	1.	1.96	.92	1.
Co	1	1.12	.80	0.91	.1	.20	.05	.12	1.	1.22	.85	.93	1.	1.16	.59	.97
Cr	1	1.08	.85	0.94	.1	.15	L .01	.14	1.	1.1	.68	.96	1.	1.03	.47	1.1
Mo	1	1.01	1.5	0.86	.1	.21	1.	.084	1.	1.41	2.4	.84	1.	1.56	6.2	.82
Pb	1	1.47	L .05	1.1	.1	.61	L .05	.27	1.	2.1	L .05	1.4	1.	2.0	L .05	1.8

TABLE 2.11(c)(i) VALUES OF PARAMETERS IN SYNTHETIC POREWATER AND SURFACE WATER SAMPLES

Constituent	Sample 7	Sample 9	Sample 10
pH	2.0	2.4	1.9
Fe (II) (mg/L)	800	1800	3400
Ca (mg/L)	360	480	450
Mg (mg/L)	125	200	70
K (mg/L)	30	60	110
SO_4^{2-} (mg/L)	3210	5470	7610
Ra-226 (Bq/L)	2.80	10.6	1.17
Th-230 (Bq/L)	0.58	5.82	0.80

Sample 1, 4 duplicate of Sample 7, but diluted 1:2.
Sample 2, 6 duplicate of Sample 9, but diluted 1:8.
Sample 3, 5 duplicate of Sample 10, but diluted 1:10.
Sample 8 duplicate of Sample 7.

Constituent	Sample 1/4	Sample 2/6	Sample 3/5
Fe(II)	400	225	340
Ca	180	60	45
Mg	63	25	7
K	15	7.5	11
SO_4^{2-}	1600	683	761

TABLE 2.11(c)(ii) ESTIMATE OF OTHER PARAMETERS IN SYNTHETIC WATER SAMPLES

	Parameter Value (mg/L)					
Sample Number	Al	Ba	K	Mn	Na	Pb
Sample 7	.015	L .002	0.001	L .003	.009	.004
Sample 9	0.2	L .002	0.013	L .003	.12	.05
Sample 10	0.027	L .002	0.002	L .003	.02	.01

Note Values of other parameters cannot be calculated because contents are not given on chemical bottles.

TABLE 2.11(c)(iii) ESTIMATE OF OTHER PARAMETERS DUE TO Al, Ba, Cd, Co, Cr, Pb ADDITION IN SAMPLE NUMBERS 7, 9, 10

Ni from Cobalt Stock	0.005 mg/L
Zn from Cobalt Stock	0.001 mg/L
Pb from Cobalt Stock	L 0.001 mg/L
Na from Cr Stock	L 0.0005 mg/L
K from Cr Stock	1.5 mg/L

TABLE 2.11(d) STOCK SOLUTIONS USED FOR PREPARATION OF SYNTHETIC WATER SAMPLES

(i) Major Elements

Element	Chemical
Fe (II)	$FeSO_4 \cdot 7H_2O$
Ca	$CaSO_4 \cdot 2H_2O$
Mg	$Mg\,SO_4$
K	K_2SO_4
SO_4^{2-}	H_2SO_4
Ra-226	NBS Certified Ra-226 Solution and CRM BL-5
Th-230	CRM BL-5

(ii) Minor Elements (for Samples 7, 8, 9, 10)

Element	Chemical
Al	Metal
Ba	$Ba\,(C10_4)_2\,3H_2O$
Cd	Metal
Co	$CoCl_2$
Cr	K_2CrO_4
Pb	$PbNO_3$

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NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
VOLUME 3 - APPENDIX 2
ATMOSPHERIC STUDIES

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A. John Chandler, P.Eng.
Project Manager

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THE GUNNAR FIELD STUDY

The Gunnar Field Study consists of 10 volumes, each published separately. Volumes 2 to 10 are supplements to Volume 1, written as Appendices 1 to 9.

The 10 volumes are:

- Volume 1 - Summary Report
- Volume 2 - Test Procedures and QA/QC Program (Appendix 1)
- Volume 3 - Atmospheric Studies (Appendix 2)
- Volume 4 - Tailings Solids and Surround Soils (Appendix 3)
- Volume 5 - Groundwater (Appendix 4)
- Volume 6 - Surface Water (Appendix 5)
- Volume 7 - Biology (Appendix 6)
- Volume 8 - Waste Rock (Appendix 7)
- Volume 9 - Eating Habits of Local Population (Appendix 8)
- Volume 10 - Permafrost (Appendix 9)

SUMMARY

ATMOSPHERIC STUDIES

INTRODUCTION

Meteorological and climatic factors affecting dust and radon releases from the tailings surfaces were evaluated during this phase of the project. In addition, radon flux rates from the surfaces of the tailings and the waste rock pile were measured, as were ambient radon levels. Spot measurements and long term average gamma data was also detected.

Meteorological and Climatic Site Description

The Gunnar mine/mill site is located on the tip of the Crackingstone Peninsula, a narrow land mass which extends southwards into Lake Athabasca from its north shore. The site may thus be characterized as an exposed headland with water on three sides. The local climate, particularly temperature, humidity, and wind speed is strongly influenced by the presence of the nearby lake during the ice-free months. Atmospheric dispersion will also be affected by the large-scale topography. There is a long fetch over the lake to the site from the east, south and west. To the north, the terrain is hilly and rolling with boreal forest, lakes and bare rock interspersed.

METHODS

Meteorological Data Collection

Meteorological measurements were made every half-hour, from December 1984 until September 1985, at a 10-metre instrumented tower located near the centre of the Gunnar Main tailings. The parameters monitored were wind speed and wind direction 10 metres above the tailings, dry-bulb temperature at the 2 m and 10 m levels, and rainfall amount, both incremental and cumulative. A satellite data connection was used to obtain the data on a regular basis. Relative humidity was also measured from May until August 1985 and the measurements were recorded on a strip chart recorder.

The meteorological tower was located near the centre of the Gunnar Main tailings at an elevation approximately 50 m above lake level (see Figure 3.1). This tailings area is roughly triangular in shape and is about 1.3 km long and 0.8 km wide. Its surface is sandy with some scattered palsas and a marshy area along the western side. The tailings slope from southeast to northwest with a total elevation change of 15 m across them. Gunnar Main is surrounded by trees and some hills. The nearest obstacle to the tower is a grove of 5 m trees situated about 50 m to the east; a 15 m hill borders the west side of the tailings about 200 m away. The north side of the tailings lies about 300 m away from the tower, the south side about 250 m. St. Mary's Channel, located about 1 km south of the tower, is the arm of Lake Athabasca nearest the tower.

Radon Flux Measurement

Although various methods have been used to determine radon emanation (Countess, 1976; Novak, 1982), the method selected for this study had to fulfill the following criteria:

- the technique should be proven in field situations;
- the system should be based on a time integrating technique in order to smooth out the large short term variations in radon flux; and
- the detector system should be commercially available, maintenance free, passive and cost effective.

The "can" and "mat" techniques developed by Fleischer (1979; 1980) were used in this project to measure radon fluxes. The methodology used a cellulose track etch detector supplied by the Terradex Corporation. In the first method, the radon flux is measured just above the surface through which the radon escapes. A tube closed at one end has the open end pressed into the soil and the radon accumulates in the closed air space above the surface. The radon concentration is measured with a track etch detector placed in the closed end of the tube. Although the concentration in the air space increases with the depth that the can is embedded into the earth, Fleischer (1982) reports that for depths greater than 2 metres the concentrations are constant.

In the "mat" technique, the radon concentration is measured above the surface using an impermeable mat which covers the radon detector.

From arguments developed by Fleischer (1979), it can be shown that, provided the value of the radius of the mat is much greater than the value of the square root bulk diffusion constant divided by the radon decay constant (which for dry tailings is about 30 cm and for moist tailings is about 10 cm), then the flux is related to the radon concentration by an expression involving porosity and the bulk diffusion constant.

The value for the bulk diffusion constant must be obtained independently from the mat technique measurement, and for this study were calculated from the measurements using the can technique.

Radon Sampler Installation

A total of 13 mat sites were installed during the winter campaign in December 1984: 8 were located on Gunnar Main, 3 on Gunnar Central, and 2 on Langley Bay. Two nests consisting of 3 cans each were installed on Gunnar Main in December. One nest was placed beside mat site M3 (and piezometer nest no. 1); the other nest was located next to piezometer nest no. 3. The samplers installed for flux measurements at both the mat and can sites were TERRADEX TYPE M samplers. The plastic detector is mounted in the bottom of a plastic cup and a special membrane to prevent the ingress of thoron is placed over the mouth of the glass. The units were all installed with the mouth facing down.

Terradex TRACK-ETCH Type 'F' detectors were deployed in protective canisters 1-metre above the ground at a total of 13 ambient monitoring sites near the 3 tailings areas. These units were used to measure radon concentrations in the air.

Gamma Measurements

Gamma radiation was measured at numerous locations using several different methods. The particular method employed depended upon the levels anticipated at the location. The majority of the sensors were thermoluminescent dosimeters (TLDs).

Radiation entering the solid-state dosimeter causes electrons in the crystal to be raised to an excited state. After a brief time (μsec) some of the electrons fall into metastable states. Electrons will remain in these states for long periods of time (months or years) under normal environmental conditions. After exposing the dosimeter in the field to measure the integrated dose, the dosimeter is read by first heating it to approximately 280°C, thereby elevating the electrons from the metastable states to the conduction band. After a short period, the electrons fall to ground state giving off light photons. By viewing this light with a photomultiplier and integrating, the exposure that the dosimeter received can be assessed by comparing the light output to that of a dosimeter whose exposure is known. Two types of TLDs were used for environmental measurements: LiF:Mg,Ti dosimeters (model TLD-100) from Harshaw Chemicals for the measurement of elevated dose rates and $CaF_2(Mn)$ dosimeters from Harshaw Chemicals for low-level dose rates.

In addition, the Radiation Protection Bureau of Health and Welfare Canada supplied TLDs for occupational monitoring purposes.

TLD devices were housed in polyethylene tubes and mounted on wooden posts driven into the ground at:

- thirteen tailngs site locations,
- thirteen ambient site locations, and
- one site on the waste rock pile.

TLDs were mounted at both surface and one metre heights to collect data on surface and ambient levels.

Waste Rock Pile Study Methods

Another potential source of gamma, radon and dust emissions on site is the waste rock pile. To quantify the extent of the impact of this source, radon flux measurements were to be made at areas of high gamma activity. This strategy required that gamma spot measurements be made with the multiple-range Berthold 'Rato/F' gamma dose-rate meter before mat sites could be selected. A survey of the waste rock pile in April showed no particular anomalies in spot gamma measurements therefore secondary mat siting criteria were employed.

To ensure proper performance one large mat (approximately 10' x 10') was deployed on the northern waste rock pile in April. Five cups were placed under the mat, one at the center, two a distance of 0.5' from the center on opposite sides of the center cup and two a distance of 1 m from the center on opposite sides of the center cup and on a line perpendicular to the axis formed by the other cups. This pattern of deployment was selected to assess mat seal at the edges.

Dust Measurements

No specific sampling activities were planned for continuous dust emission monitoring. The remote site location limited continuous dust sampling options to those beyond the fiscal capabilities of the project. Due to the late project starting time even short term sampling was not possible. Instead dust blowing from the exposed knolls was noted to be trapped downwind in the snow. By coring the snow and obtaining an indication of the total dust concentration in the core it was possible to obtain, by back calculation, an indication of the average source strength.

On March 25, 1985 two knolls of approximately 5 m^2 each were selected for the study. Samples were collected from 9 locations within 30 m of K1 and 8 locations within 30 m of K2.

Using an 8" ∅ tube a sample of the total depth of snow was taken at each location. This material was bagged. The volume of snow was converted to the water equivalent and a 50 ml aliquot of this was dried. The mass of particulate in the aliquot was used to calculate a total amount of dust in the sample volume, and samples were analyzed under the microscope to determine particle size.

Discussion of Results

The field measurement program at Gunnar covered the period from early December 1984 to September 30, 1985. Different measurements were conducted over this time and 5 site visits were utilized to collect data.

Meteorological Data

Table 1 summarizes some of the pertinent meteorological data collected at the Gunnar Main tower location.

The data suggests that mean temperatures will be above zero, or the freezing point, for at least April through September. One would expect that site conditions would be conducive to higher releases of radon and dust during this period. However, precipitation levels increase from May through August

TABLE 1: SIGNIFICANT MONTHLY METEOROLOGICAL VALUES

Month	Data Capture (%)	10m Temperature (°C)		Maximum Wind		No. of Days With Winds	No. of Days	Rain Depth
		Extreme Minimum a)	Extreme Maximum b)	Speed (km/hr)	Direction (°)**	> 20 km/hr	With Rain	(mm)
Dec. '84	*	-50	+2	36	90°	18	NA	-
Jan. '85	100	-42.6	+6.1	42.9	104°	12	NA	-
Feb. '85	99	-42.6	3.7	49.9	90°	18	NA	-
Mar. '85	98	-31.6	14.3	37.4	80°	20	NA	-
Apr. '85	77	-16.7	17.8	48.2	38°	20 out of 23	NA	-
May '85	99	- 3.4	29.6	44.1	89°	26	4	2.8
Jun. '85	99	- 0.6	35.8	34.7	341°	21	6	38.3
Jul. '85	99	4.5	35.5	37.2	285°	26	11	39.1
Aug. '85	100	3.3	33.9	33.5	113°	21	11	52.6
Sep. '85	100	- 4.9	26.0	44.7	316°	22	9	26.7

* - Tower started working Dec. 9, 1984, 2130 GMT, Data reported is after tower moved.

NA - Not available, instrument out of service until May 3, 1985.

+ - One week of data loss due to processing error at receiving station.

** - Direction wind was from based upon compass readings.

a) & b) The actual maximum and minimum temperatures recorded during the month (unlike the AES reported mean maximum and mean minimum temperature which average the daily maxima/minima for the month).

suggesting that this could attenuate dust release levels. Also it was noted that some snow remained on Gunnar Main and Langley Bay on the May 3 field trip. Ground below the tailings surface was also still frozen at this time, and extensive snow was still present off the tailings areas. Tailings were damp in June during the site visit.

Winds in the range of 15-20 kph at the surface are generally thought to be sufficient to cause saltation activity and the onset of dust emissions. Greater than 50% of the days in most months recorded some 10 m winds in excess of 20 kph. It was noticeable in the winter that wind erosion of the surface was occurring as the snow was streaked with dust from the hummocks that became exposed. It is possible that ice crystals acted as the saltating media in the winter and these may increase the extent of erosion. This situation is at odds with the conventional wisdom that assumes that when the surface is frozen no fugitive emissions occur. Spring conditions indicated that high easterly winds could cause dust clouds up to 10-15 m above the tailings. These were particularly evident with winds over 30 kph. Many of the mats on Gunnar Main were covered with blown dust during the June/July site visits.

Highest winds in the winter generally occurred from the east and its effect is shown by the high dust levels noted in the snowpack west of the two exposed knolls used for sampling.

Radon Flux

The values for the diffusion coefficient obtained from 'can' measurements tend, as expected, to be larger in spring and summer than in winter. In calculating the bulk diffusion constants for each season all values were used in determining the best estimate although it is recognized that the value for Site 8 (summer) is smaller than expected. The averages of the bulk diffusion constants for each season however do follow the expected pattern:

Bulk Diffusion Constant (cm^2/s)	Season
9.1E-4	Winter
2.6E-2	Spring
7.7E-2	Summer

These values are consistent with those reported in the literature, for example, Tanner (1964) gives a value of 8E-3 for most soils and Leach (1982) a value of 2E-2.

The values of the radon flux as estimated from the 'mat' technique are:

Radon Flux (pCi/m^2-s)	Season
4.2E-4	Winter (below snow)
3.7E-3	Spring
7.0E-3	Summer

These were calculated using the values of the diffusion constants as derived above. Although there was some concern that the high radon measurements were saturating the detectors, the short term grab samples gave results similar to those of the longer term measurements and hence gave assurance that no gross error was being made. Except where field problems were noted the results demonstrated good internal consistency and with the exception of Site 8 (summer) very good agreement was obtained between the fluxes measured by the can and mat techniques.

Ambient Radon Levels

The seasonal flux rates shown from can and mat measurements are reflected in the average ambient radon levels determined by season:

Season	Ambient Radon (pCi/L)
Winter	1.5
Spring	5.1
Summer	9.5

These illustrate a consistent increasing trend in radon levels at all sites. The highest radon flux data was recorded at site A6. Gamma dosimeter data indicates anomalies at this site. Indications are that some tailings spillage may have occurred at this location.

Radon Data from Waste Rock Pile

Mat data for 5 samplers under a large mat on the waste rock pile illustrated that the radon levels on the waste rock are significantly lower than those on the main tailings and the values recorded are all within a factor of two.

Gamma Measurements

As anticipated a slight increase in gamma readings on the tailings was recorded between winter and summer. Ambient site spot levels did not change dramatically.

The highest spot-gamma reading was measured at ambient site A6 (which also had the highest ambient radon reading from the winter period), a value of 0.65 mR/h at the 1-m level. These high readings probably result from the presence of small diameter tailings washed down from the Gunnar Main tailings.

Material composing the waste rock pile was of too heterogenous a nature for consistent spot gamma readings. In at least one instance where the 0.2-m reading was considerably higher than the 1-m reading, the cause was found to be the close proximity of a 0.2+ mR/h source.

Winter tailings dosimeter exposures were typically 1000-2000 mR at ground level while exposures at 1 metre range from 400-800 mR. There is good consistency between exposures measured by 2 dosimeters at the same site. The exposure rates varied between 100-300 μR/h at 1 metre above ground rising to between 300-600 μR/h at ground level.

Field exposure rates for the second set of tailings dosimeters varied from 300 to 700 μR/h near the surface of the tailings and 300 to 600 μR/h at a height of one metre above the surface. These rates were generally only slightly higher than those measured for the winter period as the shielding provided due to the ice, snow and water cover would be minimal. This would also be consistent with the small differences of the exposure rates near the surface and at a height of one metre. Good consistency was also found between the exposure rates measured by replicate detectors.

Waste rock pile dosimeter levels were approximately 150 μR/h regardless of height.

Normal background gamma dose rates in the study area are expected to range between 8 - 15 μR/h. Of the 14 sites surveyed in the spring, 9 sites exhibited field strengths within the range or slightly higher, less than 20 μR/h. Two sites demonstrated marginally elevated readings, sites VT-7 (22 μR/h) and site VT-1 (25 μR/h). The fields at sites VT-4 (38 μR/h) and site VT-S8 (44 μR/h) were significantly greater than expected and could be due either being located near or over a small pocket of uranium or of tailings. The field at location VT-6 was very high (810 μR/h) suggesting that the location was heavily contaminated with tailings.

The fields at the location where the dosimeters were placed for the second (summer) period appear to be slightly higher (~ 25%) than those measured during the spring period. This is not too surprising as during this period any shielding provided by snow or water would tend to be minimized and the height of the dosimeters may have varied somewhat.

Dust Data

Considerable amounts of fine material (3-65 µm with an average of 8-10 µm) was obtained from the snow cores. The absence of <3 µm material suggests that some material does become airborne even in the winter. The absence of large particles in the snow core suggests that tailings particles may not be the saltating media for winter wind erosion.

ATMOSPHERIC STUDIES

3.0 INTRODUCTION

The dose commitment due to radionuclide releases from tailings facilities is attributable to both radon and dust emissions from the source. The releases of both these contaminants are dependent upon both the physical and chemical characteristics of the tailings mass and the local climate and meteorological effects. Radon releases per unit area from tailings and waste rock vary with:

- moisture of the mass;
- porosity;
- radium concentration;
- degree of vegetative cover; and
- local barometric pressure.

Dust emissions, and the release of radionuclides and trace elements per unit area, are affected by:

- particle size distribution;
- vegetation cover;
- moisture;
- wind speed;
- wind direction versus tailings area orientation (the fetch over the surface); and
- chemical composition.

Thus, to determine emissions from the tailings, it was necessary to measure meteorological parameters influencing the releases, and this was done as part of this phase of the project. The actual physical and chemical properties of the tailings and waste rock were measured in other parts of the program and from this information it will be possible to assess the effect of these parameters on releases. This phase, however, quantified radon release rates from the surface of tailings, and measured the flux levels from waste rock so that they could be compared to tailings levels. The calculation of dose commitments are based upon yearly or lifetime exposures. This limited the necessity to collect vast amounts of data over short periods to quantify radon and dust releases and determine the mechanisms responsible for the releases. Other NUTP studies currently underway review the methods of radon measurement and determine:

- the effects of the various parameters; and
- the factors influencing fugitive dust releases from tailings sites and how they relate to Canadian tailings area releases.

Thus to characterize the tailings and waste rock area under consideration for this study, only long-term average radon emissions from the site were measured. These can be interpreted with respect to all the data amassed and used to calculate releases from other tailings sites or calibrate models of release mechanisms.

For measuring radon flux and ambient levels, several techniques are available, the various alternatives chosen are outlined in a later section of this report. The actual fugitive dust source term is not as readily measured as is the radon flux. Due to the remote nature of the site no on-going monitoring of dust levels were made. Some investigative steps were undertaken to provide limited data. These measures and the meteorological monitoring are outlined in subsequent sections.

The other component of dose commitment that needed consideration was gamma radiation levels. This was measured on and around the tailings and waste rock areas.

3.1 Site Description

3.1.1 Large-Scale Setting

The Gunnar mine/mill site is located on the tip of the Crackingstone Peninsula, a narrow land mass which extends southwards into Lake Athabasca from its north shore. The site may thus be characterized as an exposed headland with water on three sides. The local climate, particularly temperature, humidity, and wind speed is strongly influenced by the presence of the nearby lake during the ice-free months. Atmospheric dispersion will also be affected by the large-scale topography. There is a long fetch over the lake to the site from the east, south and west. To the north, the terrain is hilly and rolling with boreal forest, lakes and bare rock interspersed.

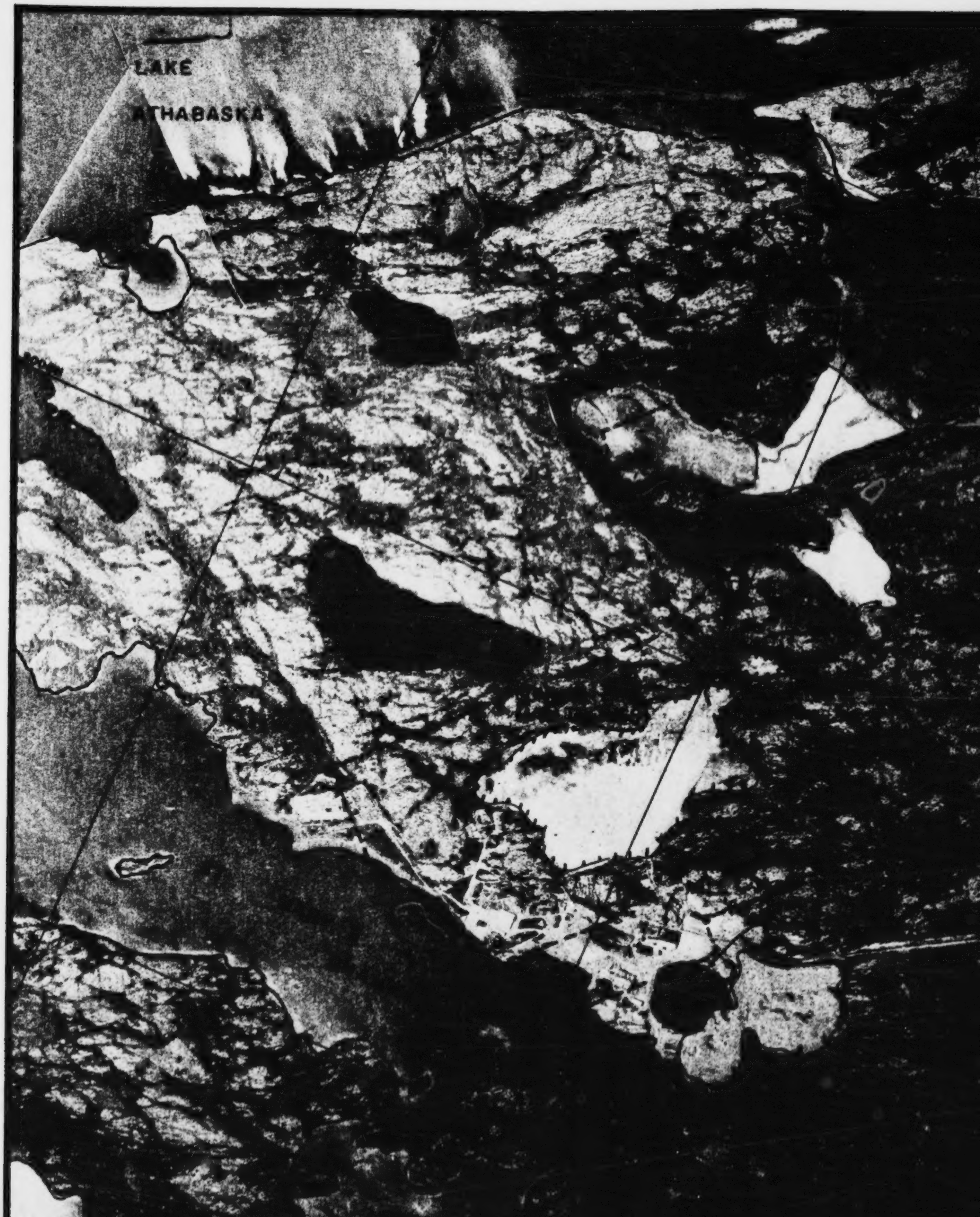
3.1.2 Small-Scale Setting

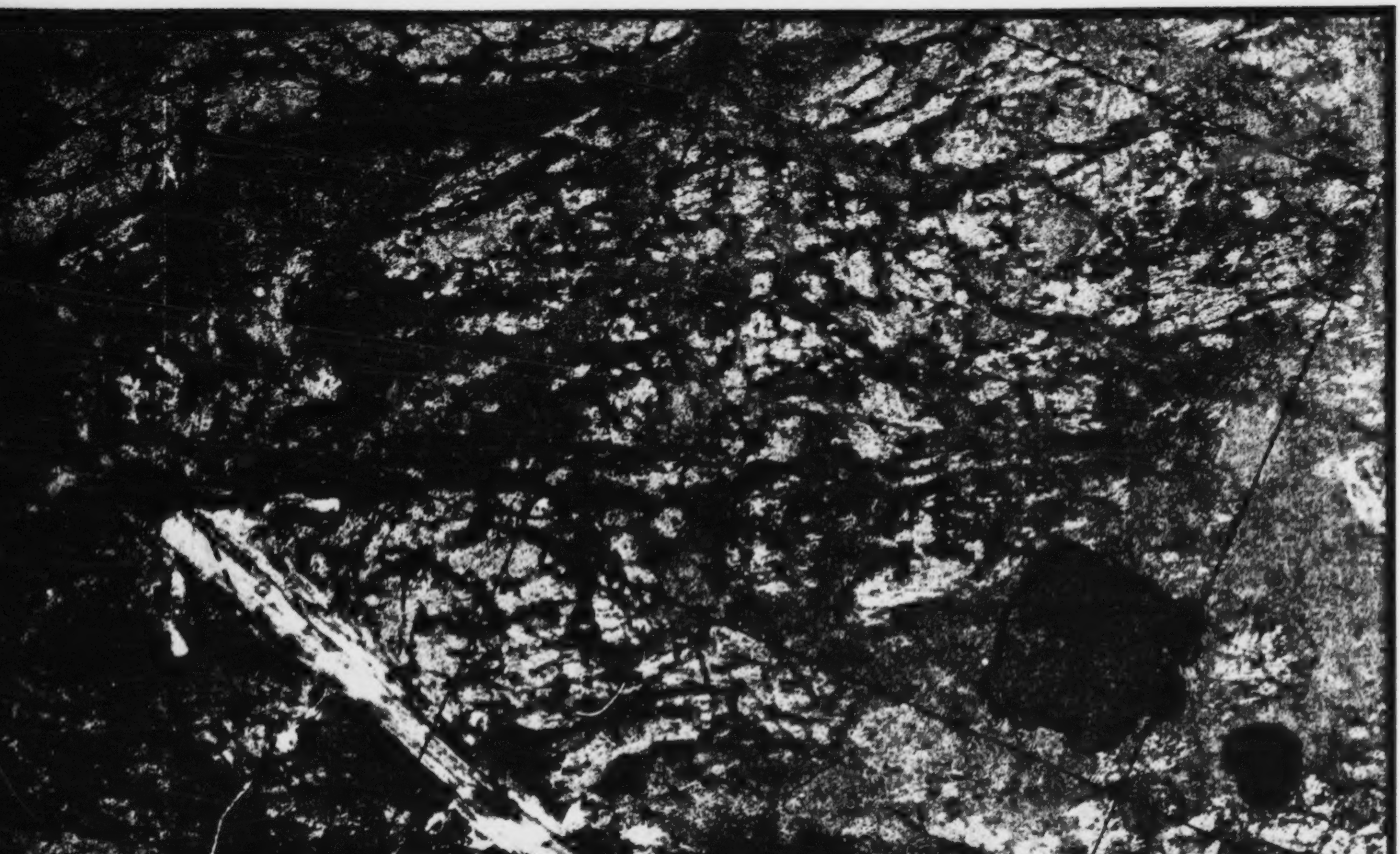
The meteorological tower was located near the centre of the Gunnar Main tailings at an elevation approximately 50 m above lake level. Figure 3.1 provides an indication of the various site features. The tailings area is roughly triangular in shape and is about 1.3 km long and 0.8 km wide. Its surface is sandy with some scattered palsas and a marshy area along the western side. The tailings slope from southeast to northwest with a total elevation change of 15 m across them. Gunnar Main is surrounded by trees and some hills. The nearest obstacle to the tower is a grove of 5 m trees situated about 75 m to the east; a 15 m hill borders the west side of the tailings about 200 m away. The north side of the tailings lies about 300 m away from the tower, the south side about 250 m. St. Mary's Channel, located about 1 km south of the tower, is the arm of Lake Athabasca nearest the tower.

3.2 Meteorological Data Collection

As part of the atmospheric component of the NUTP Gunnar Field Study, meteorological measurements were made every half-hour, from December 1984

FIGURE 3.1


LAKE
ATHABASKA



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NATIONAL URANIUM TAILINGS PROGRAM

GUNNAR FIELD STUDY

SOUTH OF URANIUM CITY, SASKATCHEWAN

SITE PLAN

SCALE 1:20000
DATE
DRAWN BY
APPROVED BY

FIGURE 3-1

until September 1985, at a 10-metre instrumented tower located near the centre of the Gunnar Main tailings (see Photo 3.1). The parameters monitored were wind speed and wind direction 10 metres above the tailings, dry-bulb temperature at the 2 m and 10 m levels, and rainfall amount, both incremental and cumulative. Relative humidity was also measured from May until August 1985. These meteorological and climate measurements will be useful for a variety of purposes, including modelling the long-term transport and diffusion of both radon gas and particulate matter at the site and calculating seasonal energy and water budgets for the area.

3.2.1 Tower Instrumentation

The instrumented tower used in this field program was a solar-powered automatic meteorological station manufactured by Handar, Inc. of Sunnyvale, California for use at remote sites (see Handar, undated). This station utilizes the satellite data collection service provided by the U.S. National Environmental Satellite Service (NESS) SMS/GOES Satellite System. Meteorological measurements are stored, processed and formatted by the Handar microprocessor-based satellite data collection system and are then transmitted every three hours to one of the GOES-series geostationary weather satellites. These data are then transmitted back to earth by the satellite to the Wallops Island (Virginia) Ground Station where they are made available to the user over a telephone link. The Saskatchewan Research Council (SRC) uses an IBM PC to access the Wallops Island computer via phone line and to then further process the data and store them.

3.2.2 Meteorological Sensors

Wind Speed Sensor

The wind speed sensor was a Met One model 013 anemometer. Its maximum operating range is 0 to 60 m/sec, starting speed is 0.5 m/sec, accuracy is ±1.5%, temperature range is -50°C to 85°C, and distance constant is less than

PHOTO 3.1

Gunnar Main showing Meteorological Tower
(White louvred box beside tower contained hygrothermograph)

15 feet. Wind speed is sampled at 15-second intervals by the Handar microprocessor. The wind speed reported is a 10-minute average for the 10-minute period ending on the half hour.

Wind Direction Sensor

The wind direction sensor was a Met One model 023 wind vane. Its starting threshold is 1.6 km/hr, azimuth range is 0° to 356°, average accuracy is $\pm 5^{\circ}$, damping ratio is 0.25, and delay distance is less than 5 feet. The wind direction is sampled by the station at 1-second intervals. The wind direction reported is a 10-minute average for the 10-minute period ending on the half hour.

Dry-bulb Temperature Sensor

Air temperature at the 2 m and 10 m levels was measured by precision bead thermistors which comprise a thermilinear network whose resistance decreases linearly with increasing temperature. Maximum temperature range is $-50^{\circ}C$ to $50^{\circ}C$, resolution is $0.4^{\circ}C$, temperature coefficient is $\pm 1^{\circ}C$, and the time constant is 10 seconds (Handar, undated). The temperature probes are located in wind-ventilated enclosures to minimize radiation effects. Sampling frequency is 1 Hz and the averaging period is 10-minutes. The recorded data was the 10-minute average ending on the half hour.

Rain Gauge

A tipping-bucket rain gauge was installed about 8 m west of the tower. Its resolution is 0.01 inches (per count) and accuracy is 0.5% at 2 inches/hour (Handar, undated). Values recorded are rain amount per half hour (incremental) and total rain amount (cumulative). Snowfall on the tailings was not recorded by this instrument. Snowpack depths were measured in late March by sounding the depth of snow on an organized grid pattern.

Relative Humidity Measurement

A battery-operated hygrothermograph with chart recorder was installed in a Stevenson screen located at the base of the tower on May 1, 1985. This instrument is capable of operating unattended for periods of 5 to 6 weeks. However, some problems were encountered in its use. When it was checked on the next site visit (June 21, 1985) the chart paper was found to have jammed after only a week or so of operation. After replacing the chart paper and batteries, clearing the housing of sand and refilling the ink reservoirs, the unit operated smoothly for several days. However, when it was next serviced (July 26, 1985) the batteries appeared to be dead and only 22 days of observations had been made. This unit was not incorporated into the satellite data system and thus could only be checked when site visits were conducted.

3.2.3 Power Supply

The meteorological tower station was powered by a 12-volt car battery which is recharged during the day by two solar panels. Battery voltage was monitored by the station and 10-minute average values are registered every half hour along with the 6 meteorological parameters. Satellite transmission cannot take place if the battery voltage drops below 10.75 V. However, an adequate power supply was provided by the solar panels even on cloudy days close to the winter solstice and no transmission problems were encountered.

3.2.4 Data Collection and Transmission System

The Handar Model 530A Remote Meteorological Station has 4 digital and 8 analog channels. It can be programmed to control the channel limits for the various sensors, the number of channels to be scanned, scan interval, scan delay, transmission interval, transmission type and transmission delay. Plug-in signal conditioning cords are used to calibrate, scale and time-average signals from the various sensors.

In the system configuration used at Gunnar, 3 digital channels (wind speed, wind direction and precipitation) and 5 analog channels (2-m temperature, 10-m temperature, battery voltage, Geiger counter and call box) were polled. Satellite transmissions were made 8 times per day at 0152, 0472, 0752, 1052, 1352, 1652, 1952 and 2252 C.S.T.

3.2.5 Installation, Calibration and Maintenance

3.2.5.1 Installation

Although the 10-metre meteorological tower and Handar system was already operating at Gunnar at the beginning of the field program, some concerns had been raised as to the suitability of its location. Upon inspection in the field, the tower was found to be poorly exposed. It was located in the grove of trees on the southern edge of Gunnar Main. A two-storey building lay about 50 m to the south of the tower and a ridge was situated a bit further away to the southwest and west. It was determined that a site near the centre of Gunnar Main would provide better exposure and allow more representative wind measurements to be taken.

Before the tower could be moved, it was necessary to ensure that proper support and guying could be provided at the new site. This was of particular concern due to the sandy surface and open nature of the tailings. Guy anchors were constructed by installing old drill casing in 3-metre-deep holes at 3 points around the tower base. Waste rock was also piled around the tower base and on top of the steel base plate for extra support.

Once the guy anchors had been installed (December 6, 1984), relocation of the tower proceeded. The tower was stripped, disassembled, moved, and ballasted on December 7, levelled, guyed, and re-equipped on December 8, and calibrated and tested on December 9. SRC personnel monitored tower transmissions during this period to ensure that the meteorological sensors and data collection/transmission system were working properly. The relocation was completed before 3:30 pm CST on December 9, 1984, at which time collection and transmission of complete half-hourly meteorological observations was resumed.

To help ensure tower performance during the winter, a new heavy-duty 12-volt car battery was installed to replace the original three-year old battery. A geiger counter and emergency call box were also re-installed on the tower at this time. The solar panels used to power the tower electronics were aimed to the south-southeast rather than to the south so that battery charging would begin as soon after sunrise as possible. (The battery is at its lowest voltage for the day just before sunrise.) As well, the transmission antenna was aimed at a point midway between two satellites, the U.S. GOES West satellite at 130°W longitude and a spare GOES satellite at 105°W longitude, to ensure signal reception in the case of the failure of one satellite. (The nominal half power beam width of the antenna is 47°.)

3.2.5.2 Calibration

Weather conditions were relatively mild during the tower relocation; winds were light and temperatures ran as high as -8°C. Nevertheless, difficulties were encountered in the disassembly and reassembly of the tower instrumentation since bare hands were required for much of the fine work. Under these conditions, only rudimentary sensor calibration was carried out. The two temperature sensors were bundled together to check their relative accuracy. Both sensors were also placed in an ice bath with a thermometer to check them against a standard reference temperature. The tower anemometer was run side by side with a mechanical wind mileage anemometer and was also inspected manually to ensure that the cup assembly moved freely with a minimum of friction. The wind vane readings were compared against rough observed near-surface wind directions and the vane was also checked for freedom of movement. The tipping bucket rain gauge mechanism was tested by manually tripping the counter.

3.2.5.3 Maintenance

Maintenance on the tower was routine for the most part. The rain gauge was cleaned and tested with 10 tips on each of December 9, 1984 (1730 GMT) and May 3 (1600 GMT), June 21 (1550 GMT) and July 27, 1985 (1750 GMT). However, the rain gauge did not register when tested on December 9, 1984 so it was taken back to Saskatoon for repair. It was subsequently re-deployed on May 3, 1985. The loss of the rain gauge data during the winter was not considered to be too important since little rain was expected to fall during that period. The 2-m temperature probe on the tower began to behave erratically on April 14, 1985 (0000 GMT) and its measurements from April 14 to 30th are strongly suspect. This probe was replaced on April 30, 1985 at 1500 GMT. Note that valid 10-m temperature are available for the entire period. No problems were apparent during the field program with any of the other tower sensors.

3.3 Radon Data Collection

The objective of this part of the study was to undertake long-term monitoring for radon flux and ambient radon levels within 1 km of the tailings area.

3.3.1 Measurement of Radon Flux

Theoretical Basis

Although various methods have been used to determine radon emanation (Countess, 1976; Novak, 1982), the method which was selected for this study had to fulfill the following criteria:

- the technique should be proven in field situations;
- the system should be based on a time integrating technique in order to smooth out the large short term variations in radon flux; and
- the detector system should be commercially available, maintenance free, passive and cost effective.

The methodology employed in this project to measure radon flux was developed by Fleischer (1980) and uses a cellulose track etch detector supplied by the Terradex Corporation. Based on tests conducted at the Environmental Measurement Laboratory, these detectors demonstrate good reproducability and a sensitivity of 13 pCi•day/L (0.5 Bq•day/L) (Alter, 1981). In order to prevent the detector responding to thoron, a filter is placed over the mouth of the detector.

The "can" and "mat" techniques were both used in this project to measure radon fluxes (Fleischer, 1979; Fleischer, 1980). In the first method, the radon flux is measured just above the surface through which the radon escapes. A tube closed at one end has the open end pressed into the soil and the radon accumulates in the closed air space where the concentration is measured with a track etch detector. Although the concentration in the air space increases with the depth that the can is embedded into the earth, Fleischer (1982) reports that for depths greater than 2 metres the concentrations are constant.

After a long exposure (T > the half-life of radon), the flux is given by the following expression:

$$J = e\ Ca\ (D\ \ell) ** 1/2\ (1 + h\ /\ (D/\ell) ** 1/2) \qquad (1)$$

where:

J is the flux (pCi/cm^2•s)
e is the porosity of the tailings material (assumed to be 0.5)
Ca is the measured radon concentration (pCi/cm^3)
D is the bulk diffusion constant (cm^2/s)
ℓ is the radon decay constant (s^{-1})
h is the height of the can above the surface (cm).

Footnote: The units of radioactivity utilized in this report are not standard SI units, pCi are utilized in place of the SI unit Bq. This convention was utilized to accommodate the readout method by which all raw analytical data was reported. The conversions between the units are:

27 pCi = 1 Bq & 1 mR = 8.7 µGy

Expression (1) can be rewritten as:

$$1/Ca = A + B\ h \qquad (2)$$

where:

$$A = e\ (D\ \ell) ** 1/2\ /\ J$$

$$B = e\ 1/J$$

Accordingly, by fitting a first degree polynomial to the data, the coefficients A and B can both be calculated and consequently values for both J and D obtained.

In the "mat" technique, the radon concentration is measured above the surface using an impermeable mat which covers the radon detector. The radon concentration under the centre of the mat is given by:

$$C = 5/6\ C^*\ r/\ (D/\ell) ** 1/2$$

where:

C* is the equilibrium radon concentration at depth (···· $(D/\ell) ** 1/2$)

r is the radius of the mat.

From arguments developed by Fleischer (1979), it can be shown that, provided the value of the radius of the mat is much greater than the value of $(D/\ell) ** 1/2$ (which for dry tailings is about 30 cm and for moist tailings is about 10 cm), then the flux is related to the radon concentration by the following expression:

$$J = e\ C\ (D\ \ell) ** 1/2$$

Thd value for D must be obtained independently from the mat technique measurement. For this study values for D were calculated from the measurements using the can technique.

Radon Flux Sampler Installation

A total of 11 mat sites were installed during the winter campaign in December 1984: 6 were located on Gunnar Main, 3 on Gunnar Central, and 2 on Langley

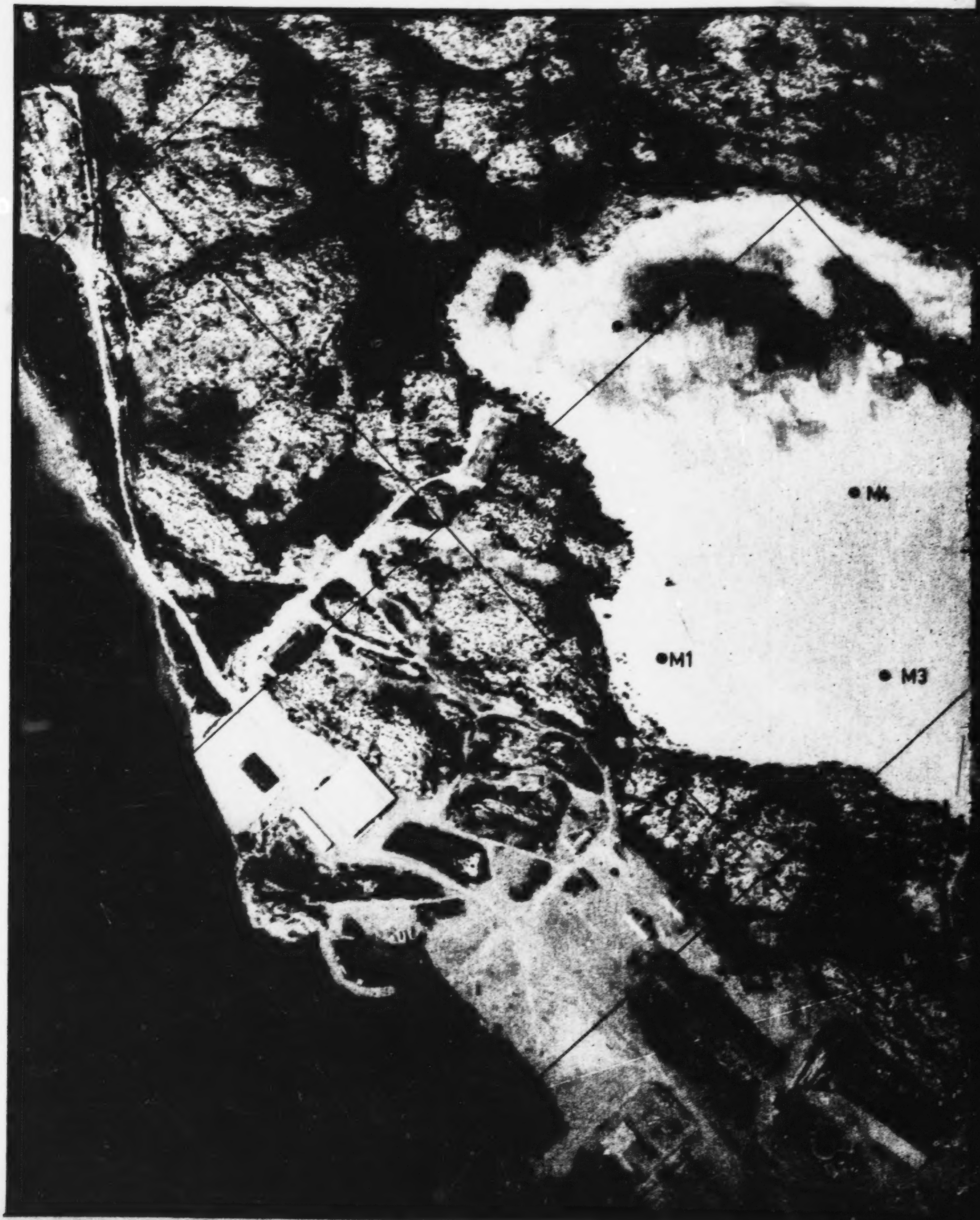
Bay. In addition, two extra sites were deployed in April 1985 (M4 and M8). The locations of these mat sites are shown in Figure 3.1. A list of mat installation and sample recovery dates is provided in Table 3.1.

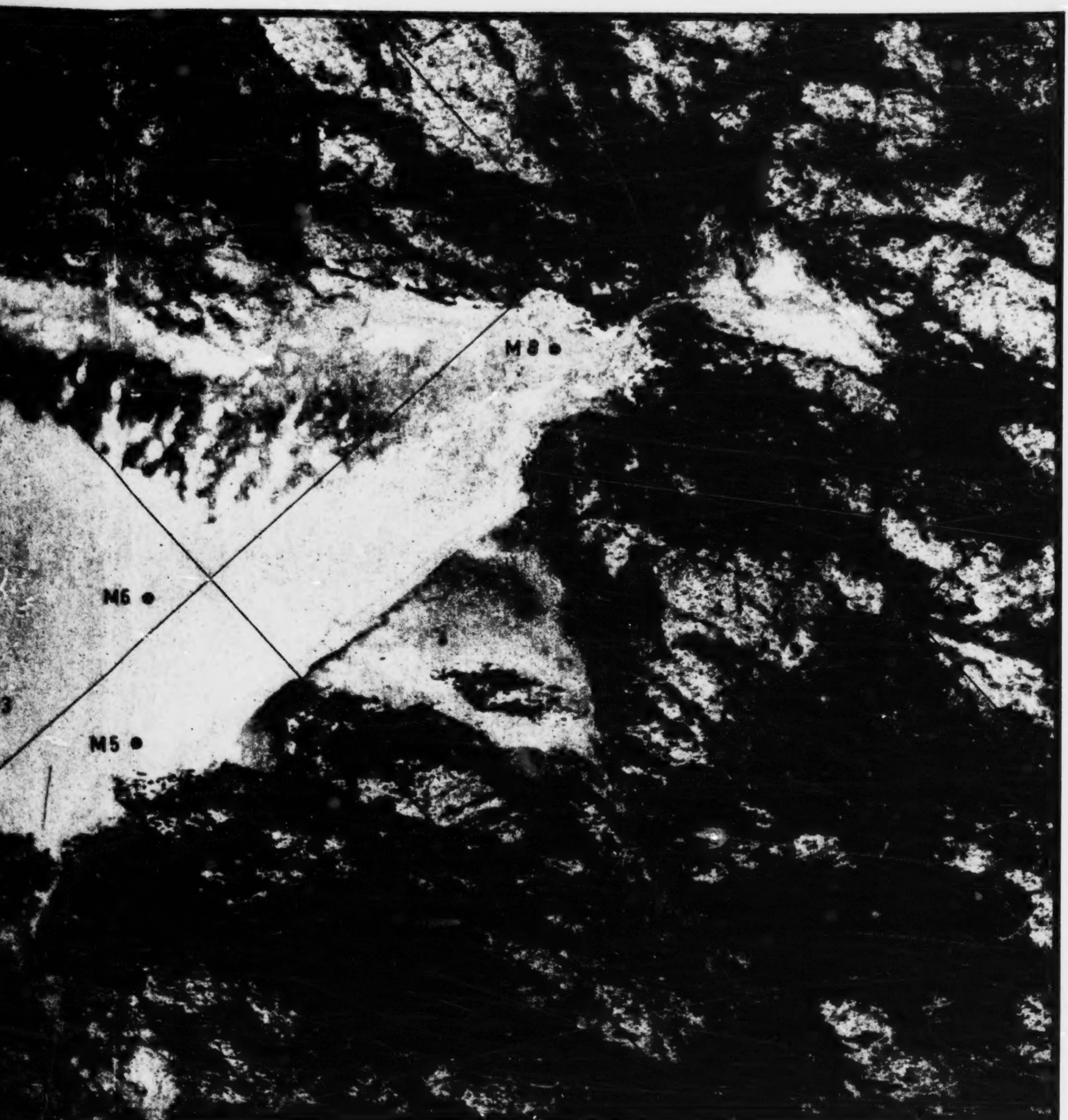
Two nests consisting of 3 cans each were installed on Gunnar Main in December. One nest was placed beside mat site M3 (and piezometer nest no. 1); the other nest was located next to piezometer nest no. 3. A list of can installation and sampler recovery dates is given in Table 3.2. A photo of a can and mat site is provided in Photo 3.2.

The samplers installed at both the mat and can sites were TERRADEX TYPE M samplers. The plastic detector is mounted in the bottom of a plastic cup and a special membrane to prevent the ingress of thoron is placed over the mouth of the glass. The units were all installed with the mouth facing down.

Selection of the mat sites was dictated by the need to collect representative flux measurements with good spatial coverage. Where possible, radon flux measurement sites were co-located with measurement sites chosen by other groups. An additional technical consideration for flux samples was the requirement that the mats not be submerged in water if at all possible. This presented site selection problems in the low-lying areas of Gunnar Main and for Gunnar Central, much of the surface of which was covered by ice in December, 1984. The flooding expected during spring runoff was also borne in mind, and a shallow trench was dug around each mat during installation. A list of the steps involved in each mat installation is provided in Table 3.3.

The presence of an extensive snowpack meant that during the selection of mat sites, holes were dug in the snow to examine the surface of the tailings at potential sites. Once a site was selected, snow was cleared from a 3 m by 3 m area. A pickaxe was used to dig the small holes needed for installation of the Terradex cups. Sand from one fairly soft area beside the main sluice on Gunnar Main was used at all mat sites.


M4
M1
M3



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ATMOSPHERIC STUDIES

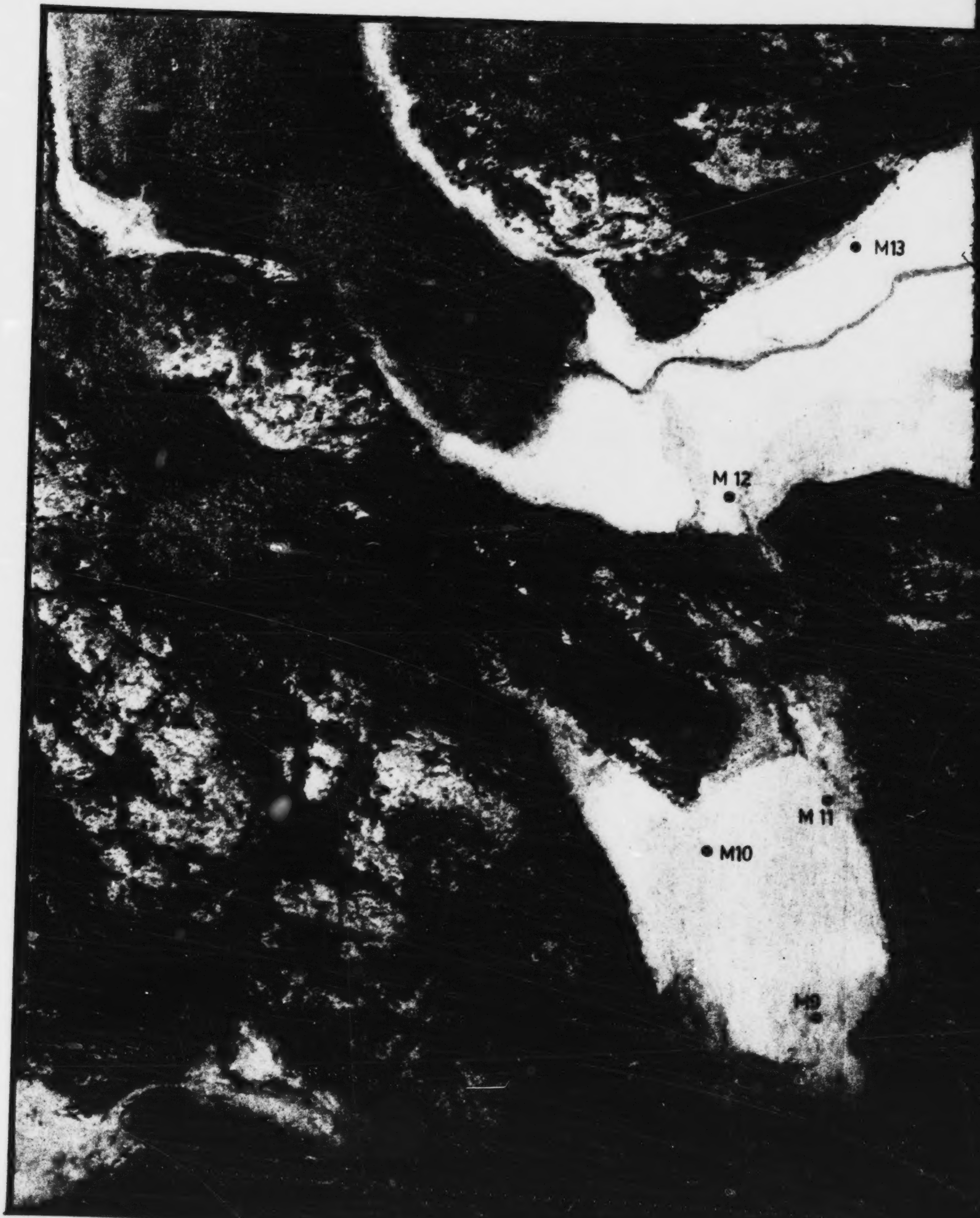
MAIN TAILINGS SAMPLING SITES

NATIONAL URANIUM TAILINGS PROGRAM

GUNNAR FIELD STUDY

SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE	DRAWN BY	FIG. 3·1a
DATE	APPROVED BY	


M13
M 12
M 11
M10
M9

SITE PLAN	SCALE 1:20000	DRAWN BY	FIGURE 3-1
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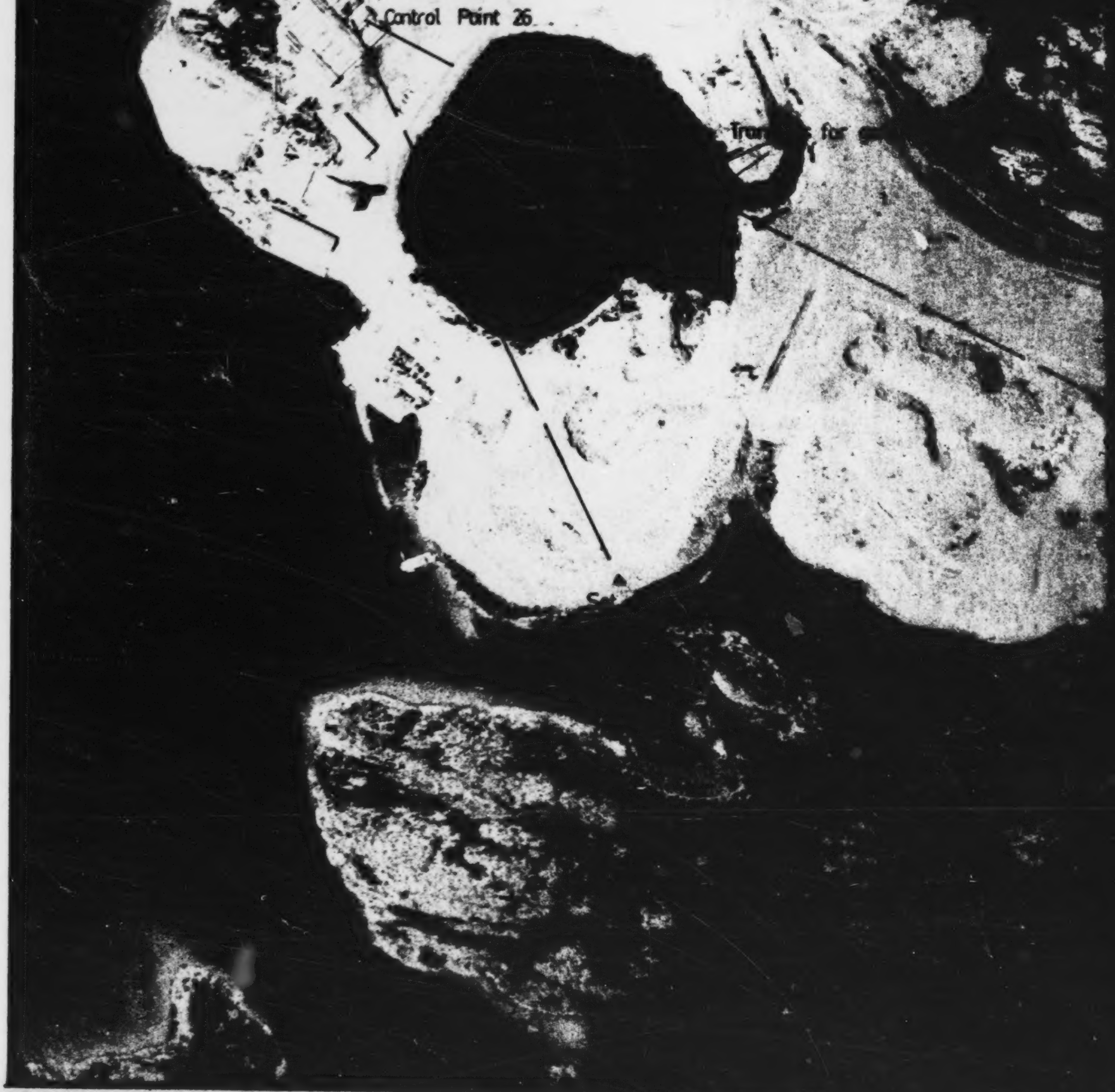
ATMOSPHERIC STUDIES

SECONDARY TAILINGS SAMPLING SITES

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE	DRAWN BY	FIG. 3·1b
DATE	APPROVED BY	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ATMOSPHERIC STUDIES

WASTE ROCK SAMPLING SITE

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE	DRAWN BY	FIG. 3·1c
DATE	APPROVED BY	

TABLE 3.1: SAMPLER DEPLOYMENT FOR TAILINGS RADON FLUX MEASUREMENT - MATS
(Terradex TRACK-ETCH Type 'M' Detectors)

Site No.	Detector No.	Installation Date	Collection Date	Spot Geiger Reading ~1 meter (mR/h)
M1	18186	02/12/84	30/04/85	0.32 to 0.35
	18277	30/04/85	23/06/85	0.38 to 0.42
	21396	23/06/85	29/07/85	0.34 to 0.38
M2	18187	02/12/84	30/04/85	0.28 to 0.32
	18250	30/04/85	21/06/85	0.30 to 0.33
	21391+	21/06/85	25/06/85	
	21393+	21/06/85	25/06/85R	
	21398	25/06/85	28/07/85	0.28 to 0.34
M3	18202	11/12/84	30/04/85	0.24 to 0.26
	18188	11/12/84	30/04/85R	
	18274	30/04/85	23/06/85	0.28 to 0.32
	18275	30/04/85	23/06/85R	
	18266	23/06/85	30/07/85	0.29 to 0.33
	18267	23/06/85	26/07/85R	
	23528+	26/07/85	30/07/85	
M4	-	-		
	18236	30/04/85	21/06/85	0.28 to 0.30
	18248+	21/06/85	25/06/85	0.32 to 0.37
	21392+	21/06/85	25/06/85R	
	21399	25/06/85	29/07/85	0.38 to 0.42
M5	18200	06/12/84	30/04/85	0.29 to 0.31
	18218	30/04/85	21/06/85	0.28 to 0.32
	18246+	21/06/85	25/06/85	
	18247	21/06/85	26/07/85	0.33 to 0.37
	23522+	26/07/85	30/07/85	
M6	18191	02/12/84	30/04/85	0.42 to 0.46
	18249	30/04/85	23/06/85	0.45 to 0.50
	18225	23/06/85	29/07/85	0.40 to 0.46
M7	18192	02/12/84	30/04/85	0.37 to 0.42
	18271	30/04/85	21/06/85	0.43 to 0.47
	21394+	21/06/85	25/06/85	
	18270+	21/06/85	25/06/85R	
	21397	25/06/85	26/07/85	0.45 to 0.48
	23525+	26/07/85	30/07/85	
M8	-			
	18278	30/04/85	21/06/85	0.22 to 0.26
	18280	30/04/85	21/06/85R	0.39 to 0.44
	18232	21/06/85	26/07/85	0.42 to 0.48
	18234	21/06/85	26/07/85R	
	23524+	26/07/85	30/07/85	
M9	18194	06/12/84	01/05/85	0.24 to 0.26
	18239	01/05/85	22/06/85	0.26 to 0.30
	18235	22/06/85	27/07/85	0.30 to 0.34
M10	18195	06/12/84	01/05/85	0.20 to 0.22
	18220	01/05/85	22/06/85	0.20 to 0.23
	18286	22/06/85	27/07/85	0.24 to 0.28
M11	18196	06/12/84	01/05/85	0.24 to 0.28
	18237	01/05/85	22/06/85	0.32 to 0.35
	18287	22/06/85	27/07/85	0.29 to 0.32
M12	18197	05/12/84	01/05/85	0.18 to 0.20
	18217	01/05/85	22/06/85	0.22 to 0.26
	18288	22/06/85	26/07/85	0.22 to 0.26
M13	18198	06/12/84	01/05/85	0.12 to 0.14
	18238	01/05/85	22/06/85	0.48 to 0.52
	18289	22/06/85	26/07/85	0.47 to 0.54

R - replicate
+ - short-term samples (4 day exposure)

1 mR/h = 8.7 μGy/h

TABLE 3.2: SAMPLER DEPLOYMENT FOR TALINGS RADON FLUX MEASUREMENT - CANS

Site No.	Can No.	Detector No.	Installation Date	Collection Date
M3	1	18201	09/12/84	30/04/85
	(tall)	18219	30/04/85	23/06/85
		21395	23/06/85	26/07/85
		23526+	26/07/85	30/07/85
M3	2	18206	10/12/84	30/04/85
	(med)	18273	30/04/85	23/06/85
		18269	23/06/85	26/07/85
		23527+	26/07/85	30/07/85
M3	3	18207	10/12/84	30/04/85
	(small)	18272	30/04/85	23/06/85
		18268	23/06/85	26/07/85
		23529+	26/07/85	30/07/85
M8	1	18193	11/12/84	30/04/85
	(tall)	18240	30/04/85	21/06/85
		18233	21/06/85	26/07/85
		23530+	26/07/85	30/07/85
M8	2	18205	11/12/84	30/04/85
	(med)	18276	30/04/85	21/06/85
		21400	21/06/85	26/07/85
		23523+	26/07/85	30/07/85
M8	3	18204	11/12/84	30/04/85
	(small)	18279	30/04/85	21/06/85
		18231	21/06/85	26/07/85
		23521+	26/07/85	30/07/85

+ - short-term exposure (4 days)

PHOTO 3.2

Typical Mat/Can Installation
(from left to right - pole for
monitoring Gamma dosimeters;
logs used to hold down mat;
3 steel pipes for can method)

TABLE 3.3: STEPS FOR INSTALLATION OF RADON FLUX MATS - WINTER CAMPAIGN

---

1. Select general area on map
2. Select site after field inspection (look for high ground, level, little or no vegetation, no ice, smooth unbroken surface, representative)
3. Clear snow from 3 m x 3 m square
4. Use broom to clear remaining snow off mat site
5. Dig 12 cm hole with pickaxe for Terradex cup
6. Place cup in hole, mark with surveyor's tape
7. Take gamma measurement above cup
8. Fill in sides of hole
9. Lay 3 polyethylene sheets, one at a time, on ground centred on cup
10. Pour sand along 4 sides of top plastic sheet near edge
11. Fold in edges of plastic sheets about 20 cm
12. Smooth plastic down, lay rocks or sand bags on top of mat edges
13. Trench around edges of mat
14. Build tripod marker over mat
15. Take mat edge length measurements

The cans were modified by cutting out teeth on the bottom of galvanized steel pipe (3" ID, 3-1/4" OD), with a welding torch. A special coupling was constructed by the driller to connect the top of the can to the drill head. The drill unit was used to rotate all 6 cans down to a depth of just under 2 metres. Approximately 5 minutes of rotation were required to install each can.

3.3.2 Ambient Radon Measurement

Terradex TRACK-ETCH Type 'F' detectors were deployed in protective canisters 1-metre above the ground at a total of 13 sites near the 3 tailings areas (Photo 3.3). These units are similar to those used for the mat and can sites except instead of utilizing a membrane, a filter was used to exclude both radon daughters and dust. The protective canisters are essentially, large inverted plastic pails which the detector assembly is placed in. Figure 3.2 shows that coverage was obtained for a variety of directions and distances from the tailings with coverage of the Gunnar Main tailings being emphasized. Two of the ambient sites, A4 and A9, contained duplicate detectors to allow a measure of sampling precision to be obtained. A list of the ambient radon detectors installed and retrieved during the campaigns is given in Table 3.4, and the installations procedures are provided in Table 3.5.

Logistics, particularly transportation, played an important role in the installation of the ambient radon monitors. One criterion for ambient site selection was that each site not be visible from the nearest access point. It was hoped that this would reduce the possibility of tampering or vandalism during the lengthy sampling period (minimum of 2 months in the field). The trail to each site was marked and documented to aid in the retrieval of samplers.

3.4 Gamma Measurements

Radon is generally considered one of the major emissions from tailings piles, but other contributions to the human dose are present. Gamma radiation is one of these. Gamma radiation was measured at numerous locations using several

PHOTO 3.3

Typical Ambient Radon Site (Site A3)
(white canister projects Terradex device;
flag to aid in location)

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ATMOSPHERIC STUDIES

AMBIENT SAMPLING SITES

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

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FIG. 3·2

Figure 3.2: Ambient Radon Sites

TABLE 3.4: SAMPLER DEPLOYMENT FOR AMBIENT RADON FLUX MEASUREMENT AND AMBIENT SPOT GAMMA MEASUREMENTS

Site No.	Detector No.	Installation Date	Collection Date	Spot Geiger Reading (mR/h)
A1	18181	09/12/84	01/05/85	0.01 to 0.02
	18257	01/05/85	23/06/85	0.03 to 0.04
	18230	23/06/85	28/07/85	0.02 to 0.03
A2	18182	09/12/84	01/05/85	0.03 to 0.04
	18260	01/05/85	23/06/85	0.03 to 0.05
	18229	23/06/85	28/07/85	0.02 to 0.03
A3	18183	30/11/84	01/05/85	0.01 to 0.02
	18256	01/05/85	23/06/85	0.02 to 0.04
	18228	23/06/85	28/07/85	0.02 to 0.04
A4	18184	30/11/84	30/04/85	0.03 to 0.05
	18253	30/04/85	24/06/85	0.05 to 0.08
	18226	23/06/85	28/07/85	0.04 to 0.06
	18174	30/11/84	30/04/85R	
	18255	30/04/85	23/06/85R	
	18227	23/06/85	28/07/85R	
A5	18185	03/12/84	01/05/85	0.02 to 0.03
	18261	01/05/85	22/06/85	0.01 to 0.02
	18245	22/06/85	29/07/85	0.01 to 0.02
A6	18176	03/12/84	30/04/85	-
	18251	30/04/85	21/06/85	0.63 to 0.67
	18295	21/06/85	28/07/85	0.60 to 0.66
A7	18177	01/12/84	30/04/85	-
	18259	30/04/85	21/06/85	0.03 to 0.05
	18294	21/06/85	28/07/85	0.02 to 0.04
A8	18178	01/12/84	30/04/85	-
	18252	30/04/85	21/06/85	-
	18291	21/06/85	28/07/85	0.01 to 0.02
A9	18179	01/12/84	01/05/85	-
	18258	01/05/85	21/06/85	-
	18292	21/06/85	28/07/85	0.01 to 0.03
	18175	01/12/84	01/05/85R	
	18254	01/05/85	21/06/85R	
	18293	21/06/85	28/07/85R	
A10	18180	04/12/84	01/05/85	0.01 to 0.02
	18263	01/05/85	22/06/85	0.01 to 0.02
	18241	22/06/85	27/07/85	0.01 to 0.02
A11	18171	03/12/84	01/05/85	0.00 to 0.01
	18264	01/05/85	22/06/85	0.00 to 0.01
	18243	22/06/85	29/07/85	0.00 to 0.01
A12	18172	04/12/84	01/05/85	0.02 to 0.03
	18262	01/05/85	22/06/85	0.02 to 0.03
	18242	22/06/85	27/07/85	0.01 to 0.03
A13	18173	04/12/84	01/05/85	0.01 to 0.02
	18265	01/05/85	22/06/85	0.03 to 0.04
	18244	22/06/85	27/07/85	0.03 to 0.06

R- Co-located replicate samplers

1 mR/h = 8.7 μGy/h

TABLE 3.5: STEPS FOR AMBIENT RADON MONITOR INSTALLATION - WINTER CAMPAIGN

1. Select general area on map
2. Select site after field inspection (look for clearing or lightly wooded area, reasonably level, low gamma background, accessible, representative, out of sight, good-sized tree or post available)
3. Clear snow from base of tree or post
4. Trim low branches, remove underbrush, nearby obstructions where possible
5. Attach protective canister to tree at 1-metre level
6. Attach marker flag to tree
7. Install Terradax cup in protective canister
8. Mark nearby objects with surveyor's tape
9. Take gamma measurement at base of tree
10. Take compass readings for 4 cardinal directions
11. Take site photos from 4 cardinal directions (and access or point-of-entry photos where necessary)
12. Locate site on topographic map of area
13. Clear and mark trail to site
14. Mark access point with double tape

different methods. The particular method employed depended upon the levels anticipated at the location. The majority of the sensors were thermoluminescent dosimeters (TLDs). Very briefly, a TLD is a solid-state device that operates on the following principle.

Radiation entering the dosimeter causes electrons in the crystal to be raised to an excited state. After a brief time (μsec) some of the electrons fall into metastable states. Electrons will remain in these states for long periods of time (months or years) under normal environmental conditions. After exposing the dosimeter in the field to measure the integrated dose, the dosimeter is read by first heating it to approximately 280°C, thereby elevating the electrons from the metastable states to the conduction band. After a short period, the electrons fall to ground state giving off light photons. By viewing this light with a photomultiplier and integrating, the exposure that the dosimeter received can be assessed by comparing the light output to that of a dosimeter whose exposure is known. Two types of TLDs were used: LiF:Mg,Ti dosimeters (model TLD-100) from Harshaw Chemicals for the measurement of elevated dose rates and CaF_2(Mn) dosimeters from Harshaw Chemicals for low-level dose rates.

3.4.1 Tailings Gamma Measurement Procedures

The dosimeters employed in this study to assess the gamma radiation fields on the tailings were TLD-100 thermoluminescent dosimeters produced by Harshaw Chemical Company. The dosimeters were placed in aluminum tubes having wall thicknesses of approximately 2 mm, the purpose of which was primarily to ensure that the dosimeter response was produced only by gamma radiation and not complicated by responding to an unknown fraction of the ambient beta field. Waterproofing was provided for the field dosimeters by placing each aluminum tube in a polyethylene tube stoppered at both ends.

EXPERIMENTAL PROCEDURE:

Annealing:

All dosimeters (field, transportation, control irradiation, and calibration TLDs) were simultaneously annealed by placing them in an oven pre-heated to 400°C for one hour. Subsequently, the TLDs were annealed for an additional 18 hours at 80°C. The initial annealing date was December 1, 1984.

CALIBRATION:

The 16 calibration dosimeters were exposed, in their aluminum containers, to a cobalt-60 radiation therapy unit, with the radiation field at the position of the dosimeters reduced to approximately 1.5 R/minute by means of a 5 cm lead attenuator. The exposure of the dosimeters was measured using a Nuclear Enterprises Model 2571 ion chamber having a calibration traceable to the National Research Council exposure standard. The accuracy of the exposures is expected to be within ±5%.

From the winter exposure period the calibration dosimeters were irradiated on March 19, 1985 to the following exposures in mR: 0, 53.7, 98.4, 303.4, 740.4, 1507, 3010, 7619.

DECAY CORRECTION:

Two dosimeters were irradiated to relatively high exposure levels before the field dosimeters were sent to site. The objectives of this procedure were:

- to enable a correction for the dosimeter phosphor's normal decay. This is normally minor, of the order of a few percent over several months.

- to identify any major problems with the TLDs which resulted in unexpectedly high or low readings. For example, if the TLDs were unknowingly placed near a heat source, a significant reduction of signal could result.

READOUT:

The dosimeters were prepared for readout by removing them from their aluminum tubes.

The TLD readout system consisted of a Harshaw Model 2000 reader interfaced to an Apple microcomputer. The system was optimized for reading out LiF dosimeters, the readout parameters being as follows:

linear heating rate	- 7°C/s
fast preheat	- 90°C
heating and light collection time	- 25 s
nitrogen flow	- 10 cfh

ANALYSIS:

The thermoluminescent (TL) reading was determined from the area of the glow curve peak with the limits of the integration being decided by visual inspection of each glow curve. Figure 3.3 shows a typical glow curve and the area selected for integration. All dosimeters should give a similar glow curve. If the peak is displaced this suggests a potentially faulty dosimeter and accordingly no result should be reported for this dosimeter.

The relation between TL reading and the exposure of the calibration TLDs is shown in Figure 3.4. The data show good linearity. The calibration dosimeters were read out in two sets, one set close to the beginning of the readout run and the other near the end. Little difference was found between the two sets which have therefore been combined.

FIGURE 3.3: TYPICAL GLOW CURVE
DOSIMETER NO. H-11-0

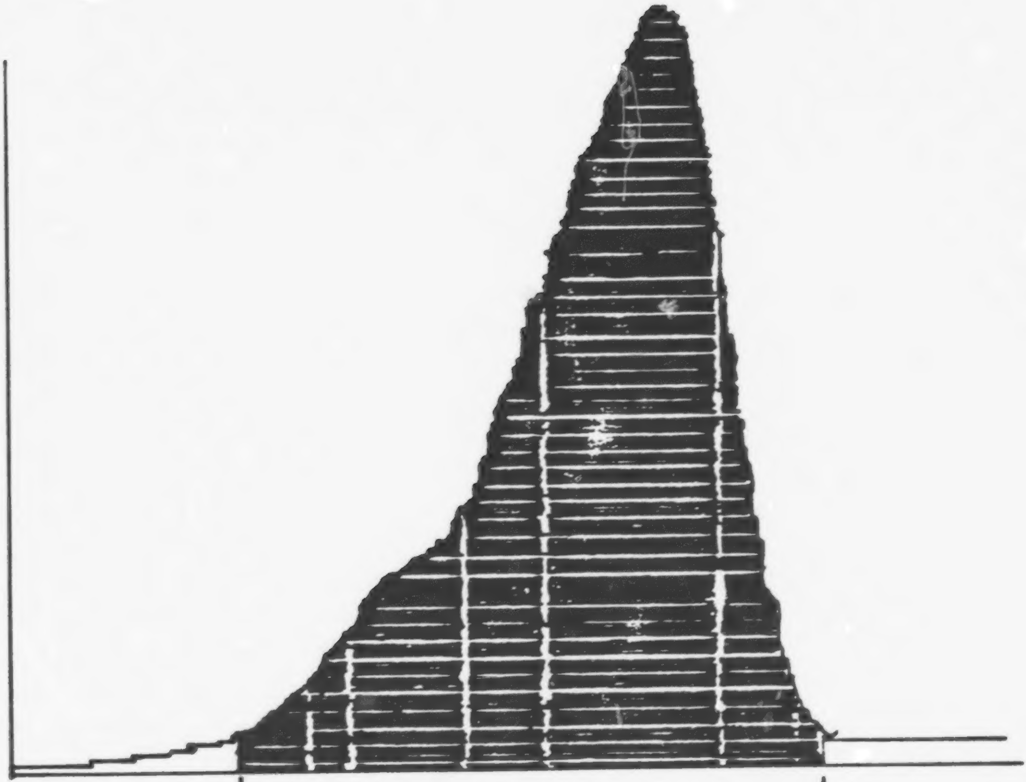
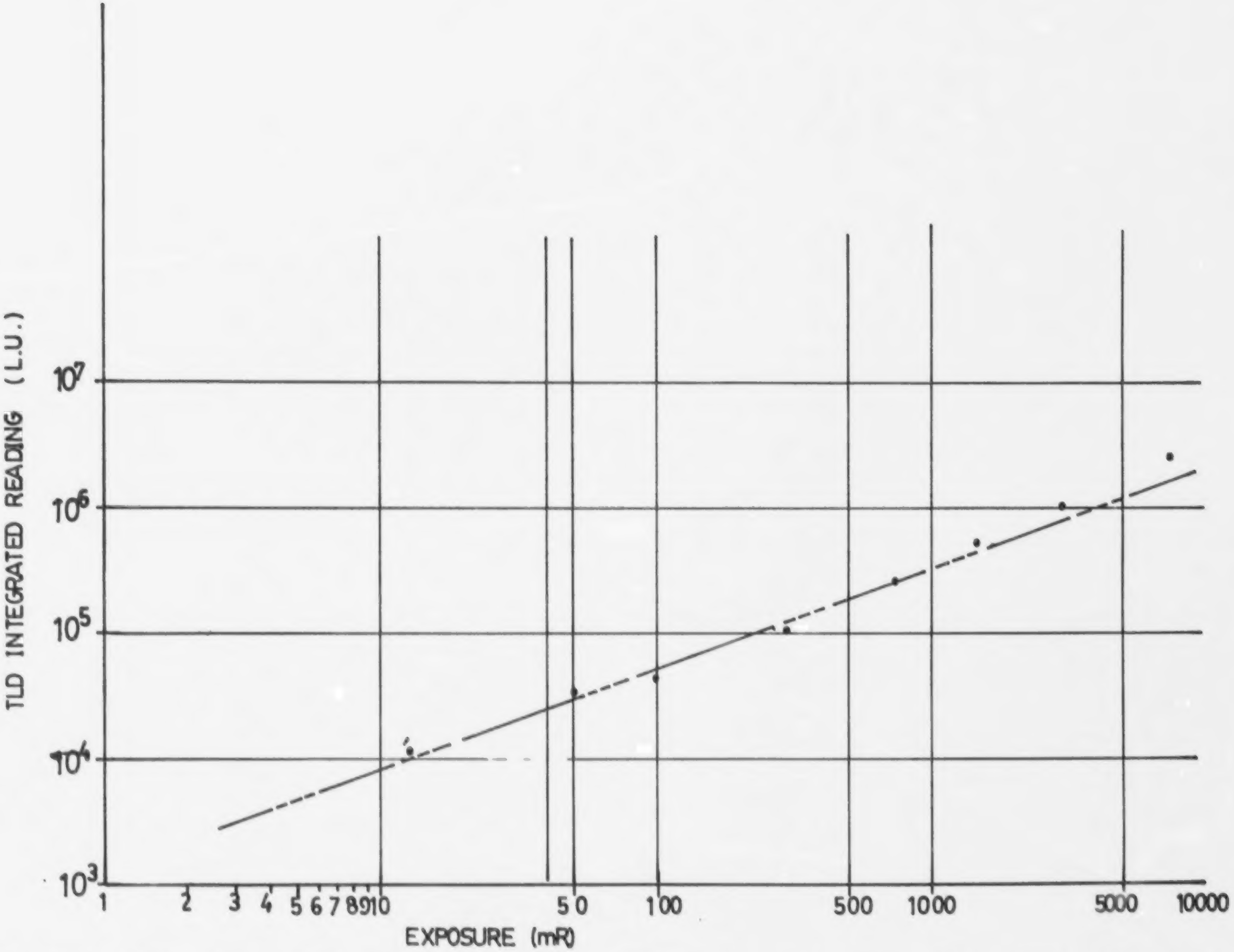


FIGURE 3.4: CALIBRATION CURVE
TLD LiF:Mg, Ti



Exposure (X) was then determined from the measured TL reading (TL) using the relationship derived from the least square fit to the calibration data, namely:

$$\mathrm{Log}(10)\ X = \{1.159\ \mathrm{Log}(10)\ (TL-T) - 3.47\}\ B$$

where:

X is the exposure (mR)

TL are the integrated light units

T is the mean reading of the transportation dosimeters

B is the decay correction factor and is equal to 1.02

(Values obtained from estimated exposure of 3141 mR on control irradiation dosimeters compared to known exposure of 3267 mr with a second order correction of a factor of 2 as the control irradiation dosimeters were irradiated at the beginning of the exposure period while the the field dosimeters were being irradiated throughout the entire period.)

Installation

The first installation of the gamma radiation dosimeters at sites on the 3 main tailings areas were accomplished at the 7 mat sites on Gunnar Main on December 10 and 11, 1984. It was not possible to deploy the gamma dosimeters on Gunnar Central and Langley Bay before the end of the first campaign due to a lack of transportation. Instead duplicate dosimeters were installed at 4 of the Gunnar Main mat sites (M3, M5, M6, and M8). Figure 3.1a shows the location of the sampling sites on Gunnar Main, and Table 3.6 lists the dosimeter installation and recovery dates.

The field dosimeters were deployed by tying them to a vertical wooden stake at 2 heights: ground level and 1 metre. Duplicate dosimeters were placed as close to the primary dosimeters as possible. The wooden stakes could not be pounded into the tailings by sledgehammer due to the hardness of the frozen ground. Rather, they were inserted into a shallow hole prepared either by using a pickaxe or the plugger drill.

TABLE 3.6: SAMPLING PERIOD FOR TAILINGS GAMMA RADIATION MONITORS
(Harshaw Lithium Fluoride TLD-100s)

Site No.	Detector No.	Installation Date	Collection Date	Sampling Time Days
M1	H1-0, H1-1	10/12/84	30/04/85	141
	VH1-0, VH1-1	30/04/85	29/07/85	90
M2	H2-0, H2-1	10/12/84	30/04/85	141
	VH2-0, VH2-1+	30/04/85	28/07/85	89
M3	H3-0, H3-1	11/12/84	30/04/85	140
	H9-0, H9-1	11/12/84	30/04/85	140
	VH3-0, VH3-1+	30/04/85	26/07/85	90
M4	VH4-0, VH4-1	30/04/85	29/07/85	90
M5	H5-0, H5-1	10/12/84	30/04/85	141
	H10-0, H10-1	11/12/84	30/04/85	140
	VH5-0+, VH5-1‡	30/04/85	26/07/85‡	87‡
			30/07/85	91
M6	H6-0, H6-1	10/12/84	30/04/85	141
	H11-0, H11-1	11/12/84	30/04/85	140
	VH6-0+, VH6-1+	30/04/85	29/07/85	90
M7	H7-0, H7-1	10/12/84	30/04/85	141
	VH7-0, VH7-1	30/04/85	26/07/85	87
M8	H8-0, H8-1	11/12/84	30/04/85	140
	H12-0, H12-1	11/12/84	30/04/85	140
	VH8-0, VH8-1+	30/04/85	26/07/85	87
M9	VH9-0, VH9-1+	01/05/85	27/07/85	87
M10	VH10-0, VH10-1+	01/05/85	27/07/85	87
M11	VH11-0, VH11-1	01/05/85	27/07/85	87
M12	VH12-0, VH12-1+	01/05/85	26/07/85	86
M13	VH13-0+, VH13-1+	01/05/85	26/07/85	86
W	VHW-0+, VHW-1	01/05/85	27/07/85	87

* 'V' indicates spring, 'H' indicates Harshaw device, '-0' indicates surface deployment, '-1' indicates deployment at the 1-metre level. 'W' indicates waste rock pile.

+ Double crystals in the dosimeter.

‡ VH5-0[1] collected 30/07/85, 91 days
VH5-1 collected 26/07/85, 87 days

[1] (see text for explanation)

The field dosimeters were accompanied to site by 2 controlled irradiation dosimeters and 5 transport dosimeters. The former were left in Uranium City in a lead-lined container along with some extra field dosimeters.

The lack of wintertime gamma dose measurements from Gunnar Central and Langley Bay is not viewed as a serious deficiency. Gamma levels are unlikely to vary much with time and gamma dose measurements were obtained for these 2 areas in the summer sampling period. It is possible that snowcover might attenuate the winter period gamma dose slightly. However, wintertime and summertime dose measurements for Gunnar Main sites can be examined to quantify this effect. Data on measurement precision was made available by using duplicate dosimeters and multiple TLD crystals.

Spot gamma measurements were also taken on the tailings areas during the winter campaign with a multiple-range Berthold 'Rato/F' gamma dose-rate meter. Measurements were hand-held averages for about 30 seconds at the 1-metre level.

3.4.2 Background Gamma Measurement Procedures

Since background gamma levels were expected to be considerably lower than those present on the tailings areas, more sensitive CaF_2:Mn gamma dosimeters were used for these measurements.

The CaF_2(Mn) dosimeters employed in this study to assess the gamma radiation fields on the tailings thermoluminescent dosimeters were produced by Harshaw Chemical Company. The dosimeters were wrapped in 4.8 mm of polyethylene over which was placed a 1.7 mm thick cover of tin foil. This filtration was used to minimize the large over-response of the dosimeter to photons below 300 Kev, which approaches a value of 15 between 20 and 80 Kev (McKinlay, 1980). The filtration selected is similar to that discussed by Szabo (1980) for the $CaSO_4$:Dy dosimeter (which exhibits approximately the same energy dependence as the CaF_2:Mn dosimeter), and accordingly will result in essentially an energy independent response for gammas with energies greater than 100 Kev. Waterproofing for field units was provided by placing each dosimeter in a polyethylene tube stoppered at both ends.

EXPERIMENTAL PROCEDURE:

Annealing:

All dosimeters (field, transportation, control irradiation, and calibration TLDs) were simultaneously annealed by placing them in an oven pre-heated to 350°C for one hour. The annealing date was April 11, 1985.

Calibration:

The 16 calibration dosimeters were exposed in their containers by a cobalt-60 radiation therapy unit, with the radiation field at the position of the dosimeters reduced to approximately 1.5 R/minute by means of a 5 cm lead attenuator. The exposure of the dosimeters was measured using a Nuclear Enterprises Model 2571 ion chamber having a calibration traceable to the National Research Council exposure standard. The accuracy of the exposures is expected to be within ±5%.

The dosimeters were irradiated on June 17, 1985 to the following exposures in mR: 0, 25, 75, 150, 300. For the analysis, a correction was made for the exposures that the dosimeters received from annealing to readout.

CONTROL IRRADIATION:

Two dosimeters were irradiated to relatively high exposure levels (1888 mR) before the field dosimeters were sent to site. The objectives of this procedure were:

- to enable a correction for the dosimeter phosphor's normal decay. This is normally minor of the order of a few percent over several months.
- to identify any major problems with the TLDs which resulted in unexpectedly high or low readings. For example, if the TLDs were unknowingly placed near a heat source, a significant reduction of signal could result.

READOUT:

The dosimeters were prepared for readout by removing them from their filters. The dosimeters were analyzed on July 8, 1985.

The TLD readout system consisted of a Harshaw Model 2000 reader interfaced to an Apple microcomputer. The system was optimized for reading out LiF dosimeters, the reaadout parameters being as follows:

o linear heating rate	- 7°C/s
o fast preheat	- 50°C
o heating and light collection time	- 25 s
o nitrogen flow	- 10 cfh

ANALYSIS:

The thermoluminescent (TL) reading was determined from the area of the glow curve peak with the limits of the integration being decided by visual inspection of each glow curve. Figure 3.5 shows a typical CaF_2 (Mn) glow curve and the area selected for integration. All dosimeters gave similar glow curves.

The relation between TL reading and the exposure of the calibration TLDs is shown in Figure 3.6. The data show good linearity as demonstrated by the least square polynomial fit where the maximum percentage deviation is less than

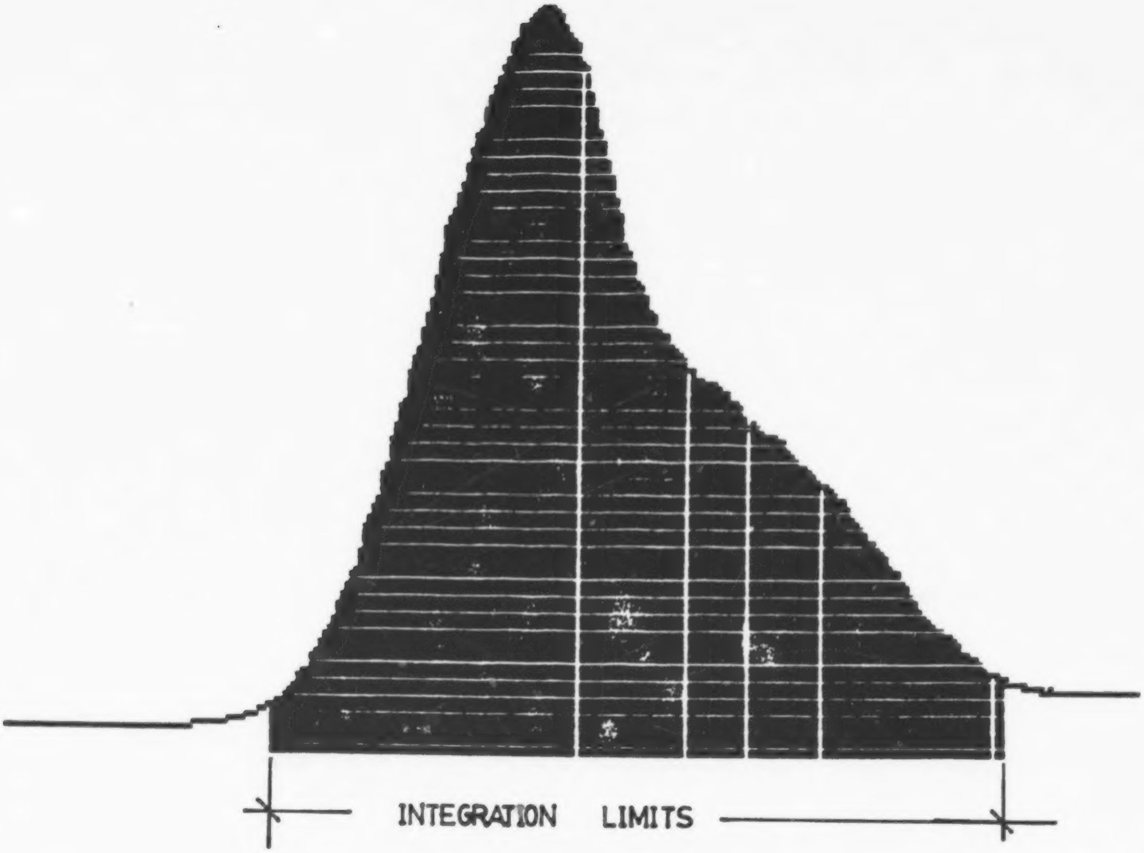
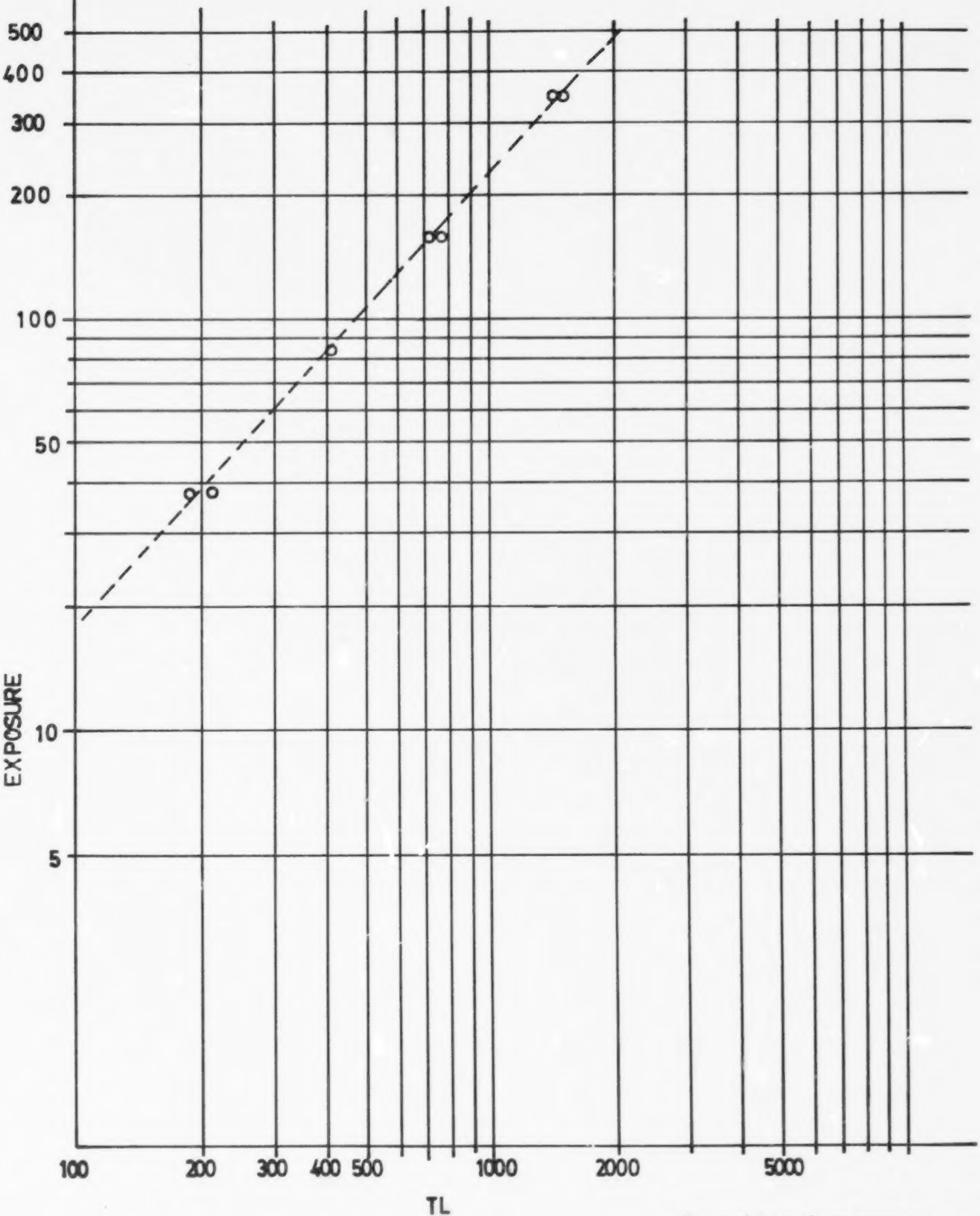


FIGURE 3.5: CaF_2 (Mn) GLOW CURVE

FIGURE 3.6: CaF_2 (Mn) CALIBRATION CURVE



38. The calibration dosimeters were read out in two sets, one set close to the beginning of the readout run and the other near the end. Little difference was found between the two sets which have therefore been combined.

Exposure (X) was then determined from the measured TL reading (TL) using the relationship derived from the least square fit to the calibration data, namely:

$$\mathrm{Log}(10)\ X = \{1.130\ \mathrm{Log}(10)\ (TL-T) - 1.029\}\ B$$

where:

X is the exposure (mR)

TL are the integrated light units

T is the mean reading of the transportation dosimeters. (A second order correction was made to compensate for the exposure that the transportation dosimeters received during the time the background dosimeters were deployed on site.)

B is the decay correction factor and is equal to 1 as within the experimental accuracy no decay was observed from the analysis of the control irradiation dosimeters.

Installation

As with the tailings TLDs the CaF_2:Mn dosimeters were housed in polyethylene tubes and these were affixed to posts at the ambient radon sites. All background gamma TLDs were deployed at the 1 metre height. A list of sampler deployment and retrieval dates are provided in Table 3.7.

3.5 Waste Rock Pile Study Methods

Another potential source of gamma, radon and dust emissions on site is the waste rock pile. To quantify the extent of the impact of this source, radon flux measurements were to be made at areas of high gamma activity. This strategy required that gamma spot measurements be made with the multiple-range Berthold 'Rato/F' gamma dose-rate meter before mat sites could be

TABLE 3.7: SAMPLER DEPLOYMENT FOR BACKGROUND GAMMA MONITORS
(CaF_2:Mn Dosimeters)*

Site No.	Dosimeter No.	Installation Date	Collection Date	Sampling Time Days
A1	VT-1	01/05/85	23/06/85	53
	ST-1	23/06/85	28/07/85	35
A2	VT-2	01/05/85	23/06/85	53
	ST-2	23/06/85	28/07/85	35
A3	VT-3	01/05/85	23/06/85	53
	ST-3	23/06/85	28/07/85	35
A4	VT-4	30/04/85	23/06/85	54
	ST-4	23/06/85	28/07/85	35
	VT-1VTS8	30/04/85	23/06/85R	54
	ST-14	23/06/85	28/07/85R	35
A5	VT-5	01/05/85	22/06/85	52
	ST-5	22/06/85	29/07/85	37
A6	VT-6	30/04/85	21/06/85	52
	ST-6	21/06/85	28/07/85	37
A7	VT-7	30/04/85	21/06/85	52
	ST-7	21/06/85	28/07/85	37
A8	VT-8	30/04/85	21/06/85	52
	ST-8	21/06/85	28/07/85	37
A9	VT-9	01/05/85	21/06/85	51
	ST-9	21/06/85	28/07/85	37
A10	VT-10	01/05/85	22/06/85	52
	ST-10	22/06/85	27/07/85	35
A11	VT-11	01/05/85	22/06/85	52
	ST-11	22/06/85	29/07/85	37
A12	VT-12	01/05/85	22/06/85	52
	ST-12	22/06/85	27/07/85	35
A13	VT-13	01/05/85	22/06/85	52
	ST-13	22/06/85	27/07/85	35
U.C. Storage	UC STOR	24/06/85	30/07/85	36

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* All dosimeters contain duplicate CaF_2:Mn crystals and were deployed at the 1-m level.

selected. A survey of the waste rock pile in April showed no particular anomalies in spot gamma measurements therefore secondary mat siting criteria were employed.

One of the difficulties of utilizing the mat technique for measuring flux is to ensure that a diffusion barrier of the correct properties is installed. These properties include the ability of the barrier to distort the equal radon concentration lines so that surface measurements approximate values for a greater depth. Sealing of the edges of the mat thus becomes important. To achieve the best seal the mat site chosen was:

- undisturbed, no drill holes or other activity had been conducted;
- free of holes, which could change the diffusion patterns;
- of uniform granular surface nature with no visible rocks; and
- close to the center of the pile, to minimize edge effects in pile.

One large mat (approximately 3 m x 3 m) was deployed on the northern waste rock pile in April. Five cups were placed under the mat, one at the center, two a distance of 0.5 m from the center on opposite sides of the center cup and two a distance of 1.0 m from the center on opposite sides of the center cup and on a line perpendicular to the axis formed by the other cups. This pattern of deployment was selected to assess mat seal at the edges since it was thought that sealing would be more difficult on the pile due to the greater porosity of the surface. A listing of the cups installed at this mat site is given in Table 3.8. Two gamma dosimeters were also installed on a wooden stake beside the mat (Table 3.6).

In June, the 5 TRACK-ETCH cups under the large mat on the waste rock pile were replaced (see Table 3.8), and a gamma radiation survey of the pile was conducted. The survey consisted of spot gamma readings taken at the 1 m and 0.2 m levels at 73 locations on the top of the pile. Locations were ascertained using a surveyor's transit and the known locations of horizontal control points 1

TABLE 3.8: SAMPLER DEPLOYMENT FOR WASTE ROCK PILE RADON FLUX MEASUREMENT - LARGE MAT

Detector No.	Position Relative to Centre of Mat	Installation Date	Collection Date
18283	0	01/05/85	24/06/85
18222		24/06/85	27/07/85
18282	1m N	01/05/85	24/06/85
18290		24/06/85	27/07/85
18281	1m S	01/05/85	24/06/85
18224		24/06/85	27/07/85
18284	0.5m E	01/05/85	24/06/85
18221		24/06/85	27/07/85
18285	0.5m W	01/05/85	24/06/85
18223		24/06/85	27/07/85

and 26 (see BBT - Air Photo Mosaic showing Test Hole Locations NUTP Gunnar Field Study, Drawing No. 584-1750-2).

The final samplers were retrieved in late July.

3.6 Dust Measurements

No specific sampling activities were planned for continuous dust emission monitoring. The logistics of 120 VAC power supply to run conventional high volume samplers precluded their use and acquisition costs excluded employing TSI Model 3911 fugitive dust monitors. Fortuituously the 1985/86 winter season had high winds and it soon became noticeable that some mounds on the tailings were being stripped of snow and dust was blowing across the snow surface (Photo 3.4). This provided a means of obtaining an indication of the extent of the winter dust situation.

Dust blowing from the knoll was trapped downwind in the snow. By coring the snow and obtaining an indication of the total dust concentration in the core it is possible to obtain an indication of the extent and magnitude of dust releases.

On March 25, 1985 two knolls of approximately 5 m^2 each were selected for the study. Samples were collected from 9 locations around K1 and 8 locations around K2. Using the ordinate directions N, E, S and W the samples were taken a 15 m N, 10, 20 and 30 m E, 10 and 20 m S and 10, 20 and 30 m W of K1. Around K2 samples were taken from 10 m N and S and 10, 20 and 30 m E and W of the centre of the knoll.

Using an 8" Ø tube a sample of the total depth of snow was taken at each location. This material was bagged in large plastic sample bags and returned frozen to the BEAK laboratories in Toronto. The volume of snow was converted to the water equivalent and a well mixed 50 ml aliquot of this was dried. The mass of particulate in the aliquot was used to calculate a total amount of dust in the sample volume.

PHOTO 3.4

View of Gunnar Main
showing dust drift across snow surface

Subsequently, samples from the original sample were also analyzed under the scanning electron microscope to determine particle size. Sample of the surface materials from both knolls were subjected to chemical analysis as well as microscopic analysis.

3.7 Quality Control/Quality Assurance Procedures

Steps were taken throughout the project to check the results being obtained and improve reliability and precision. Meteorology measurement instruments were checked before monitoring started when erratic behaviour in temperature data in April prompted the installation of a new monitor in late April. The rain gauge was actuated on each visit to ensure that the operation was proceeding normally.

All sampling units for radon and gamma monitoring were carefully packaged and shipped to and from site. Limited replicates of some samplers were installed during most field campaigns. Gamma dosimeters were shipped with transportation and irradiated blank dosimeters to ensure the identification of any anomalous problems with the field units. The identification of replicates and procedures for blanks and irradiated samples are outlined in the preceeding section.

Original data on radon flux measurements caused some concern. When the TRACK-ETCH detectors were processed and read, a substantial number of tracks were found. The laboratory identified this to the CSC project team and following discussions, it was agreed that the readings should be cross-checked. Duplicate samplers were one possibility but the preferred solution was to use a shorter exposure time to lessen the number of tracks. As a check, it was also decided that samplers would be exposed for the duration of the field site visit on the May and July visits. Thus we would obtain a short-term sample which would have only a limited number of tracks on it. The replicate and short-term radon samplers are denoted in the preceding sections.

Comparison of the TRACK-ETCH data for similar stations identified potential anomalies. If these could not be readily explained, the laboratory was requested to reaccess the levels. Only 10 values were questioned and only the corrected levels are presented in this document.

3.8 **RPB Measurements**

During the study the occupational exposure of on-site personnel to ionizing radiation was monitored by means of the Thermoluminescence Dosimeter (TLD) service provided by the Radiation Protection Bureau (RPB). These units are similar to those used for the Gunnar survey described earlier in this report.

Radiation damage depends on the absorption of energy from the radiation and is proportional to the concentration of absorbed energy in the tissue. The 'REM' (Radiation Equivalent Man) or more recently the 'Sievert' (Sv) are units of measure, adopted largely for radiation safety purposes, to express the radiation dose equivalent. The dose equivalent expressed in REM or sieverts considers the absorbed dose (measured in rads) as well as the quality factor (i.e., the type of radiation), non-uniform distribution and other factors beyond the scope of this explanation.

The Occupational Radiation Hazards Division of the Radiation Protection Bureau (Health and Welfare Canada) maintains a TLD service. This organization has published signal levels of dose equivalent based on a maximum amount per quarter year as well as a cumulative year, for each of the four exposure scenarios: body, skin, head and extremities. These are summarized in Table 3.9.

Field crews were monitored with respect to the cumulative dose to the body and skin (body: 30 mSv per quarter; 50 mSv per year; skin: 150 mSv per quarter; 300 mSv per year). Four sets of dosimeters were submitted covering the periods as follows:

TABLE 3.9: HEALTH AND WELFARE CANADA DOSE EQUIAVALENT CRITERIA (AS MEASURED BY FILM BAGE)

Type	Quarter Year (mSv)*	Yearly (mSv)
Body	30	50
Skin	150	300
Head	80	150
Extremities	380	750

- o Period 1 - November 15, 1984 to February 1, 1985;
- o Period 2 - February 1, 1985 to May 15, 1985;
- o Period 3 - May 15, 1985 to August 15, 1985; and
- o Period 4 - August 15, 1985 to November 15, 1985.

The following presents a discussion of the reported dose equivalent values for each period as well as for the one year cumulated dose. The actual results (by individual) are presented in Chapter 3.14.

Period 1

All fifteen dosimeters submitted for analysis indicated the exposure to be less than 0.2 mSv for the three month period (November 1984 to February 1985).

Period 2

The sixteen dosimeters submitted for analysis resulted in dose equivalent readings which ranged from less than 0.2 (N = 11) to 0.4 (N = 1) for both the body and skin (February 1985 to May 1985).

Period 3

Eleven dosimeters were submitted for analysis covering the period of May 1985 to August 1985. The results for personal dosimeters ranged from less than 0.2 to 0.3 mSv. Sample 1085-142468 indicated exposure levels of 1.2 mSv (body) and 2.2. mSv (skin). Subsequent information indicates that this dosimeter was placed or misplaced on the ground in the tailings area.

Period 4

Twelve dosimeters were submitted for analysis covering the period from August 1985 to November 1985. All exposures were reported to be less than 0.2 mSv.

SUMMARY

As evident from the above, the results of the occupational radiation exposure program are unspectacular. The highest reported value for a body exposure recorded on a worker's badge during his period on site was 0.4 mSv which is seventy-five times (75x) lower than the permissible quarterly dose and three hundred and seventy-five times (375x) lower than the permissible yearly dose. Similarly, the highest reported value for a worker skin exposure was 0.4 mSv which is three hundred and seventy-five time (375x) lower than the permissible quarterly dose and seven hundred and fifty times (750x) lower than the permissible yearly dose.

3.9 Results

The results of all measurement activities undertaken for the atmospheric programme are presented in this section. Discussion of pertinent observations and findings are contained in the next section of the report.

3.9.1 Meteorological Data Set

A quite detailed, high quality meteorological data set has been produced. Wind speed, wind direction and temperature data are available every half hour for the period December 9, 1984, 1530 CST until September 30, 1985, 2330 CST. Although several gaps do occur in the record, overall data recovery of 97%+ was achieved. A one-week gap from April 1 to April 8, 1985 was due to a processing error at Wallops Island. A number of much shorter gaps of several hours occurred due to instances of poor satellite transmission quality. As mentioned previously, the 2-m temperature data from April 14, 1985 to April 30, 1985, is considered unreliable due to apparent problems with the temperature probe.

Half-hourly precipitation data, both incremental and cumulative, are available in the data set for the period May 3, 1985, 1600 GMT until September 30, 1985, 2330 CST. Note that three tests of 0.5 inches each are included in the total data set, and the cumulative rainfall figure.

The Gunnar meteorological data set is stored on an IBM PC floppy disk along with a programme to read and print the data. Chapter 12 of this volume contains a listing of the programme used to retrieve data from the storage disk. Hard copy of the data is available in three ring binder form if required. The file name is Gunnar. Table 3.10 shows a sample listing from the file. Temperatures are given in degrees Celcius, wind speed in kph, wind direction in degrees (meteorological convention), precipitation in tenths of millimetres.

The relative humidity data covers intermittent periods from May 3, 1985 until September, 1985. The chart paper provides handcopy of the data but this has been reduced to tabular form. Table 3.11 provides the available hourly average RH data in % by day and month.

3.9.2 Radon Flux Data

Results of the TERRADEX analysis of TRACK ETCH dosimeters used for mat and can method determinations of flux are provided in Chapter 13 of this volume. The data is in the form received from the laboratory with sample numbers being used to identify the sample locations. The sample locations can be determined from Table 3.1 for mats and Table 3.2 for the cans.

Utilizing the methods outlined earlier the data was reduced to provide radon flux measurements from both methods. Table 3.12 provides the data for the can technique and Table 3.13 for the mat technique.

3.9.3 Ambient Radon Data

As with the radon flux measurement results the ambient radar results are presented in Chapter 13 of this volume. The sampler numbers are cross-referenced to data in Table 3.4.

TABLE 3.10: SAMPLE OF METEOROLOGICAL TOWER DATA (AUGUST 21, 1985)

GUNNAR DCP SITE 1985

4240105A 09-03-1985

UNIVERSAL TIME DD	HH	MM	WIND SPEED (KPH)	WIND DIR. (DEG)	ACC. PREC. (MM)	INCR. PREC. (MM)	BATT. MONI. (V)	AIR TEMP. (2M) (C)	AIR TEMP. (10M) (C)	TOT. RAD. (mR/h)	CALL CIR
233	0	0	7.6	315	901.4	0.3	12.7	12.7	11.9	0.07	14.0
233	0	30	9.5	329	901.7	0.3	12.7	12.3	11.9	0.28	15.0
233	1	0	9.2	350	901.7	0.0	12.7	12.3	11.9	0.24	15.0
233	1	30	8.1	314	902.0	0.3	12.7	12.3	11.9	0.17	15.0
233	2	0	10.4	316	902.5	0.5	12.6	12.3	11.9	0.16	15.0
233	2	30	10.1	316	902.7	0.3	12.7	12.3	11.9	0.17	15.0
233	3	0	7.1	315	903.0	0.3	12.7	11.9	11.5	0.11	15.0
233	3	30	8.8	313	903.2	0.3	12.7	11.9	11.5	0.16	15.0
233	4	0	5.6	317	903.2	0.0	12.7	11.9	11.5	0.24	15.0
233	4	30	5.2	323	903.2	0.0	12.7	11.9	11.9	0.20	15.0
233	5	0	7.6	314	903.2	0.0	12.6	12.3	11.9	0.16	15.0
233	5	30	7.2	319	903.2	0.0	12.7	12.3	11.9	0.12	15.0
233	6	0	7.6	318	903.2	0.0	12.7	12.3	11.9	0.26	15.0
233	6	30	8.3	327	903.2	0.0	12.7	12.3	11.9	0.21	15.0
233	7	0	8.0	323	903.2	0.0	12.7	11.9	11.9	0.10	15.0
233	7	30	8.9	322	903.2	0.0	12.7	11.9	11.9	0.22	15.0
233	8	0	7.5	319	903.2	0.0	12.6	11.5	11.5	0.25	15.0
233	8	30	6.9	323	903.2	0.0	12.7	11.5	11.5	0.23	15.0
233	9	0	8.0	331	903.2	0.0	12.7	11.5	11.5	0.23	15.0
233	9	30	8.1	325	903.2	0.0	12.7	11.2	11.2	0.16	15.0
233	10	0	6.9	327	903.2	0.0	12.7	11.5	11.5	0.16	15.0
233	10	30	7.3	337	903.2	0.0	12.7	11.5	11.5	0.31	15.0
233	11	0	4.5	342	903.2	0.0	12.6	11.5	11.5	0.23	15.0
233	11	30	4.4	338	903.2	0.0	12.7	11.5	11.5	0.15	15.0
233	12	0	12.8	348	903.2	0.0	12.7	11.9	11.5	0.17	15.0
233	12	30	6.8	20	903.2	0.0	12.7	11.9	11.5	0.25	14.0
233	13	0	9.2	20	903.2	0.0	12.7	11.9	11.5	0.26	15.0
233	13	30	12.5	19	903.2	0.0	12.7	11.5	11.2	0.23	15.0
233	14	0	11.0	15	903.2	0.0	13.0	11.9	12.3	0.30	15.0
233	14	30	10.4	4	903.2	0.0	13.5	12.3	12.3	0.08	15.0
233	15	0	10.5	28	903.2	0.0	13.7	13.5	13.1	0.18	15.0
233	15	30	12.8	23	903.2	0.0	13.8	15.1	13.9	0.25	15.0
233	16	0	8.4	52	903.2	0.0	13.5	13.9	13.1	0.16	15.0
233	16	30	9.4	352	903.2	0.0	13.4	13.9	13.1	0.30	15.0
233	17	0	9.3	3	903.2	0.0	13.3	14.3	13.5	0.17	15.0
233	17	30	9.4	317	903.2	0.0	13.5	15.5	14.7	0.18	15.0
233	18	0	12.9	341	903.2	0.0	13.5	15.1	14.3	0.25	15.0
233	18	30	10.7	337	903.2	0.0	13.5	15.1	14.3	0.29	15.0
233	19	0	5.8	322	903.2	0.0	13.6	16.6	15.5	0.14	15.0
233	19	30	6.2	311	903.2	0.0	13.6	16.2	15.1	0.18	15.0
233	20	0	12.3	308	903.2	0.0	13.6	17.0	15.5	0.24	15.0
233	20	30	10.6	315	903.2	0.0	13.7	17.4	15.9	0.22	15.0
233	21	0	11.3	278	903.2	0.0	13.9	20.2	18.6	0.22	15.0
233	21	30	8.9	320	903.2	0.0	13.8	17.0	15.9	0.15	15.0
233	22	0	9.7	312	903.2	0.0	13.7	19.4	17.8	0.25	15.0
233	22	30	16.0	296	903.2	0.0	13.7	18.6	17.4	0.12	15.0
233	23	0	7.2	131	903.2	0.0	13.4	16.6	15.9	0.22	15.0
233	23	30	8.2	137	903.2	0.0	13.3	19.0	17.8	0.23	15.0

TABLE 3.11 a): MAY HYGROTHERMOGRAPH
AVERAGE HOURLY RELATIVE HUMIDITY DATA
(% RH) BY DAY

HOUR	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	AVG.
DAY																									
1																		24	25	25	26	27	29	31	(26.7)
2	32	34	37	43	48	50	55	58	55	55	56	52	46	46	43	35	34	31	31	31	34	37	39	40	42.6
3	44	47	50	51	54	57	57	56	51	49	49	44	41	39	38	37	35	37	39	41	43	47	49	51	46.1
4	59	67	68	72	76	79	81	85	87	86	82	78	75	69	62	61	59	56	57	61	67	67	68	69	70.5
5	72	78	80	82	82	83	82	79	77	75	70	67	65	64	60	58	54	52	51	50	52	57	62	67	67.5
6	71	73	76	81	85	88	89	89	84	80	79	78	76	73	72	72	71	70	70	71	74	78	81	82	77.6
7	85	87	88	91	93	94	93	86	79	74	68	60	58	50	50	49	48	50	59	67	66	72	83	91	72.5
8	92	87	90	93	93	94	95																		(92.0)
9																									
10																									
11																									
12																									
13																									
14																									
15																									
16																									
17																									
18																									
19																									
20																									
21																									
22																									
23																									
24																									
25																									
26																									
27																									
28																									
29																									
30																									
31																									

Note: Blanks indicate missing data due to instrument failure.

TABLE 3.11 b): JUNE HYGROTHERMOGRAPH
AVERAGE HOURLY RELATIVE HUMIDITY DATA
(% RH) BY DAY

HOUR	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	AVG.
DAY																									
1																									
2																									
3																									
4																									
5																									
6																									
7																									
8																									
9																									
10																									
11																									
12																							30	29	(29.5)
13	28	29	29	28	28	28	30	33	37	40	41	41	42	43	44	45	46	45	45	43	41	42	45	45	38.2
14	45	43	39	42	40	41	45	46	45	47	54	58	62	64	69	70	68	62	60	57	62	61	58	50	53.7
15	43	40	40	40	41	43	46	48	51	54	61	69	77	89	92	84	66	45	41	42	43	45	46	43	53.7
16	43	42	42	43	42	39	39	45	54	55	58	61	59	59	63	65	65	63	59	55	51	58	45	42	52.0
17	39	37	35	34	33	33	37	40	47	52	51	60	73	74	69	67	63	57	51	46	40	33	29	29	47.0
18	29	28	27	34	40	43	51	67	69	68	69	69	71	70	64	50	49	48	49	49	44	39	35	30	49.7
19	23	23	19	17	16	22	40	39	37	37	32	29	25	20	18	17	13	16	22	23	29	34	41	49	26.7
20	51	52	58	61	68	70	69	68	59	69	53	41	74	61	50	40	33	24	18	17	48	52	24	60	50.9
21													(70.5)												
22	32	30	28	27	26	22	20	19	18	25	33	37	(28.7)												
23	32	32	31	28	26	25	23	25	26	28	33	35	34.8												
24	27	28	28	27	25	25	26	29	30	31	35	40	32.4												
25	61	54	65	57	69	68	67	66	65	71	81	86	65.3												
26	44	40	38	35	33	32	31	31	32	35	44	57	56.0												
27	30	28	25	24	22	20	22	22	24	27	29	31	39.4												
28	35	31	25	19	18	17	16	17	19	21	25	32	33.5												
29	28	26	23	21	20	20	21	21	22	24	29	32	32.3												
30	59	53	50	46	37	35	32	30	32	47	58	66	54.5												

Note: Blanks indicate missing data due to recorder pen failure.

TABLE 3.11 c): JULY HYGROTHERMOGRAPH
AVERAGE HOURLY RELATIVE HUMIDITY DATA
(% RH) BY DAY

HOUR DAY	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	AVG.
1	76	81	83	83	80	75	65	55	54	58	56	55	53	50	41	33	28	25	26	30	34	34	35	35	51.9
2	40	42	47	54	59	61	60	48	51	41	30	20	18	24	31	49	70	66	52	58	57	60	66	65	48.7
3	64	80	79	71	78	80	71	61	59	60	55	47	40	38	32	33	35	38	40	45	49	55	61	63	55.6
4	64	72	81	84	86	85	83	76	60	52	56	60	55	45	54	59	54	49	47	42	42	51	65	75	62.4
5	83	83	84	85	89	85	74	63	52	46	37	32	29	27	26	25	25	26	27	44	66	72	72	81	55.5
6	86	88	85	86	91	91	87	79	67	55	42	37	36	33	50	75	81	86	91	87	78	78	74	65	72.0
7	51	60	69	59	54	49	45	47	53	54	61	60	70	81	78	78	80	83	84	71	64	59	55	50	63.1
8	58	62	69	74	72	66	58	50	48	46	66	81	90	91	94	90	82	68	53	50	55	69	64	70	67.7
9	65	69	71	72	71	69	65	65	61	52	49	44	39	37	35	34	40	75	80	79	74	71	73	73	61.0
10	74	70	64	62	60	58	54	52	51	50	49	49	48	53	71	83	90	91	92	93	95	95	91	79	69.7
11	69	69	88	92	91	86	75	67	64	55	49	43	62	78	77	78	82	85	90	89	92	94	92	89	77.3
12	89	93	97	96	89	76	65	58	54	63	81	85	82	81	82	79	77	69	59	68	86	92	95	97	79.7
13	90	77	64	58	57	55	64	84	85	88	94	91	88	85	79	71	68	64	67	70	60	55	54	53	71.7
14	51	46	39	65	66	61	65	64	65	64	65	65	68	69	63	60	61	59	58	57	55	58	72	85	61.7
15	81	84	86	90	94	93	92	93	94	92	90	65													(87.8)
16																									
17																									
18																									
19																									
20																									
21																									
22																									
23																									
24																									
25																									
26												45	40	37	36	38	60	74	69	71	72	82	87	88	(61.5)
27	81	81	82	82	81	80	76	65	56	52	49	46	39	53	71	77	73	59	61	72	72	79	81	82	68.7
28	85	86	88	89	86	82	77	69	62	53	43	41	39	44	43	40	40	39	39	39	45	50	49	51	57.5
29	53	56	65	73	82	81	77	70	63	61	58	51	39	33	30	26	24	24	25	29	39	60	70	72	52.5
30	73	75	78	77	75	73	69	55	45	42	41	38	34	31	28	25	20	19	25	34	43	50			(47.7)
31										43	40	38	33	29	28	27	25	25	29	30	35	42	48	53	(35.0)

Note: Blanks indicate missing data due to instrument failure.

TABLE 3.11 d): AUGUST HYGROTHERMOGRAPH
AVERAGE HOURLY RELATIVE HUMIDITY DATA
(% RH) BY DAY

HOUR DAY	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	AVG.
1	44	44	44	44	46	47	47	47	44	40	37	33	32	34	39	38	36	34	39	48	54	54	51	53	42.9
2	56	57	59	67	72						54	52	50	47	47	46	44	44	43	44	49	54	61	63	(53.1)
3	66	69	74	75	78	81	82			73	74					55	61	62	63	66	66	68	75	82	(70.6)
4	88	88	86	87	91	95	91	81	75	74			65	62	59	53	55	57	56	60	66	65	69	74	(72.6)
5	81	89	92	89	87	90	90	90	91	92	92	89	88	81	75	73	67	62	62	62	67	74	78	82	81.0
6	86	85	85	86	84	86	91	88	90	89	82	82	87				55				45	42	43	48	(71.3)
7	53	60	60	59	59	59	59	60	63	67	67	67	62	63	59				49	48	47	47	50	53	(57.7)
8	56	61	65	67	68	76	82	84	83	83										49	48				(68.5)
9		49	51	56	65	68	80	83	85	83	80	78	72											45	(68.8)
10	44	47	49	61	79	87	90	89	81	70	70	74	79	78	74									39	(69.4)
11	40	40	42	46	56	71	78	74						62	66	64	62	60	56				38	40	(55.9)
12	47	53	57	61	68	79	83	86			90	88	88	81	80	85	82					68			(74.7)
13					61	62	62	65	68	73	78	79	81	83	85	90			90	85	83	82	81	80	(77.1)
14	79			75	74	71	76	75	75	74	74	76	75	74	75	81	88	92	94	93	91	85			(79.8)
15										59	73	85	86			81	81	81			81	80	78	77	(78.4)
16												61	83	70	75	80	85	88	93	95	93	95	94	92	(83.4)
17	81															60			71	77	74	79			(73.4)
18					71													46	51	52	55	57	62	61	(56.9)
19	63	64									36	35	35	36	38	40			47	49	51	53	54	58	(46.9)
20	58	59	59	61	61	59						55	54	53	53					61	71	76	83	89	(63.5)
21	89	89	89				84	88	93	92	91	91			90	90	91	92	90	91	90	91			(90.1)
22				85	85	86	85	85	85																(85.2)
23	93									80															(86.5)
24										85	89														(87.0)
25																									
26											89	88													(88.5)
27																									
28																									
29																									
30																									
31																									

Note: Blanks indicate missing data due to instrument failure.
Indicate indecipherable data (per failure).

TABLE 3.12: RADON FLUX MEASUREMENTS FROM 'CAN' TECHNIQUE

Time Period	Location	Diffusion Coefficients (cm^2/s)	Flux (pCi/cm^2-s)
Winter	#3	1.64 E-3	4.98 E-4
	#8	6.84 E-4	1.47 E-4
Spring	#3	4.95 E-2	8.04 E-3
	#8	1.45 E-2	2.36 E-3
Summer	#3	2.20 E-2	1.08 E-2
	#8	2.40 E-3	3.65 E-4
July Grab	#3	1.83 E-1	8.36 E-3
	#8	9.98 E-2	4.00 E-3

Notes: 27 pCi= 1 Bq

TABLE 3.13: RADON FLUX AS DETERMINED BY 'MAT' TECHNIQUE

	Radon Flux (pCi/m^2-s)				
Site	Winter	Spring	June Grab	Summer	July Grab
1	2.3 E-4	3.5 E-4(1)		7.2 E-3(4)	
2	4.8 E-4	3.9 E-3	1.5 E-3	6.2 E-3	
3	3.9 E-4	4.6 E-3		1.5 E-3	6.2 E-3
4		3.5 E-3	3.4 E-3	7.6 E-3	5.1 E-3
5	3.1 E-4	4.1 E-3	3.3 E-3	3.8 E-3	2.6 E-3
6	4.8 E-4	3.7 E-3		4.9 E-3	
7	4.8 E-4	4.6 E-3	5.0 E-4	4.8 E-3	2.7 E-3
8		1.3 E-3		1.2 E-2	4.2 E-3
9	5.3 E-4	3.8 E-3		1.3 E-2	
10	4.9 E-4	3.6 E-3		3.8 E-3	
11	4.8 E-4	1.8 E-4(2)		1.5 E-2	
12	4.0 E-4	3.5 E-3		5.4 E-3	
13	5.0 E-4	1.2 E-4(3)		6.1 E-3	

Notes: 27 pCi= 1 Bq

(1) Result suspect - Condensation on detector noted.
(2) Result suspect - Cup tilted and above ground.
(3) Result suspect - Cup moved from initial position.
(4) Result possibly low - Plastic mat shredded.

Site staff observations of the sampler condition upon retrieval are an important consideration when one reviews the results. The winter survey ambient monitors were in excellent shape when recovered. Unfortunately the same cannot be said for samplers from the other periods. The June field trip revealed that none of the detectors had been directly affected by the growth of vegetation during the spring. However, the integrity of 3 detectors had been compromised by animals. Ambient site A6 is located at a tree east of the Gunnar Main tailings, 300 m from the earthen berm. The filter of the radon detector at this site had been shredded, and the 1-m horizontal pole supporting the CaF_2:Mn gamma dosimeter had been torn from its anchor and lay on the ground at the base of the tree. As well, the gamma dosimeter had been detached from the fallen pole and had tooth marks on its weatherproof housing. The protective canister housing the TERRADEX radon detector was still attached to the tree. From evidence of browsing near the site, as well as a large number of spoor and copious amounts of scat, we concluded that the site had been "investigated" by a large ungulate, most likely a moose.

Ambient sites A9 and A13 are both situated high on the rocks west and east of Gunnar Central, respectively. At both sites there was evidence of damage most probably caused by an inquisitive bear. At duplicate site A9, one of the two radon detectors (serial no. 18258) had had its filter shredded, and the pole holding the CaF_2:Mn gamma dosimeter lay, splintered, on the ground adjacent to its host tree.

Site A13 is situated in the middle at a berry patch, and at this site the radon cup's filter had been shredded; the Gamma dosimeter and atttached pole lay on the ground; the site's identifying orange flag had been torn from the tree and lay on the ground, shredded; the plastic ring holding the filter was in pieces and the detector cup was cracked, and there was bear feces within 3 metres of the detectors. All of these facts lend support to the "curious bear" theory.

Similar occurrences were noted on the July trip to site. At ambient sites A6, A7, A10, A11 and A12, the filters on the radon cups were shredded.

The data has been included in the appendix where the cups were recoverable but some careful consideration of the results is required. Summary results for the ambient sites are provided in Table 3.14.

3.9.4 Gamma Measurement Data

As noted in the methods section Gamma measurements were made in several ways. The results of these measurements are presented in tabular form in this section of the report.

3.9.4.1 Spot Gamma Measurements

Hand-held meter readings of gamma levels were obtained from each sampler site. Ambient site gamma spot readings for the spring and summer period are provided in Table 3.15. Gunnar Main and Langley Bay spot gamma data are shown in Table 3.16.

In addition to the tabular data for designated sampling sites, December 1984 spot measurement data from various locations on Gunnar Main are provided in Figure 3.7.

Spot gamma measurements for the waste rock pile are provided in Table 3.17. These data were collected in June 1985.

3.9.4.2 Tailings Gamma Dosimeter Readings

The gamma dosimeter measurements from the tailings areas were conducted between December 1984 and April 1985. Results of the dosimeter analysis are presented in Table 3.18.

3.9.4.3 Ambient Gamma Dosimeter Readings

Ambient site gamma dosimeter data was collected for two periods in the spring and summer. The results are summarized in Table 3.19.

TABLE 3.14: SUMMARY RESULTS OF AMBIENT RADON DATA BY SEASON (pCi/L)

(replicates shown in brackets)

Site No.	Dec/May	May/June	June/July
A1	0.94	5.72	6.69
2	1.37	3.11	8.39
3	2.21	4.42	8.39
4	2.68(2.27)	6.72(4.23)	10.36(3.86)
5	0.75	4.69	12.48
6	8.39	14.58	23.92*
7	0.48	3.93	6.06
8	0.41	9.26	9.27
9	0.32(0.34)	0.13(3.82)	6.33(5.26)
10	0.38	3.36	7.26*
11	0.40	3.93	6.86*
12	0.33	1.98	10.08*
13	0.60	4.50	7.82
Exposure Time Range (Days)	139-151	52-55	35-39

* filter damaged
1 Bq/L = 27 pCi/L

TABLE 3.15: AMBIENT SITE SPOT GAMMA READINGS (mR/hr)

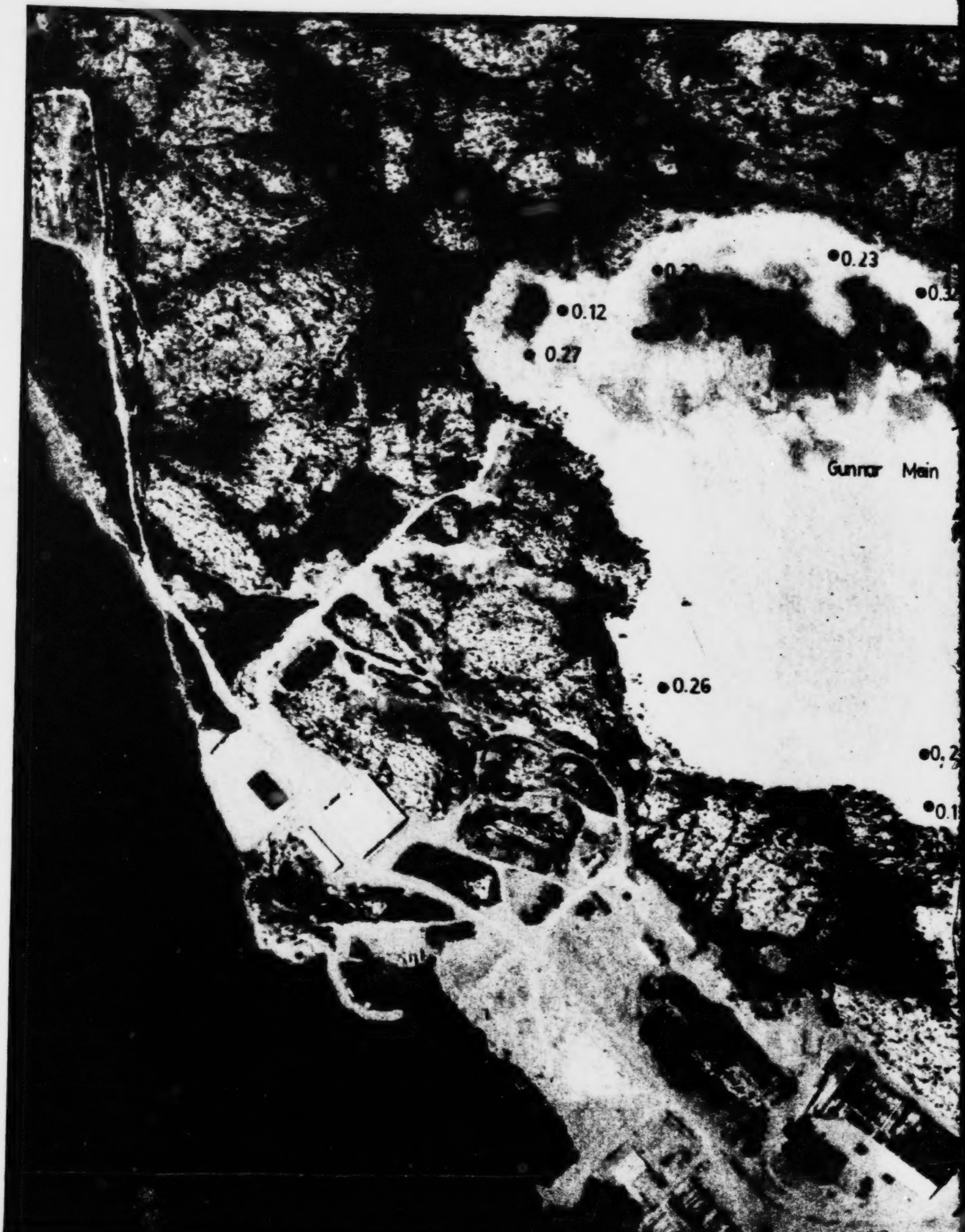
Site No.	Period Dec	May	June	July
A1	0.02	0.02	0.04	0.02
2	0.02	0.04	0.04	0.02
3	NA	0.02	0.03	0.03
4	0.03	0.04	0.06	0.05
5	0.02	0.03	0.02	0.02
6	NA	NA	0.65	0.63
7	0.04	NA	0.04	0.03
8	0.02	NA	NA	0.02
9	0.02	NA	NA	0.02
10	0.02	0.02	0.02	0.02
11	0.01	0.01	0.00	0.00
12	0.03	0.03	0.02	0.02
13	0.04	0.02	0.04	0.04

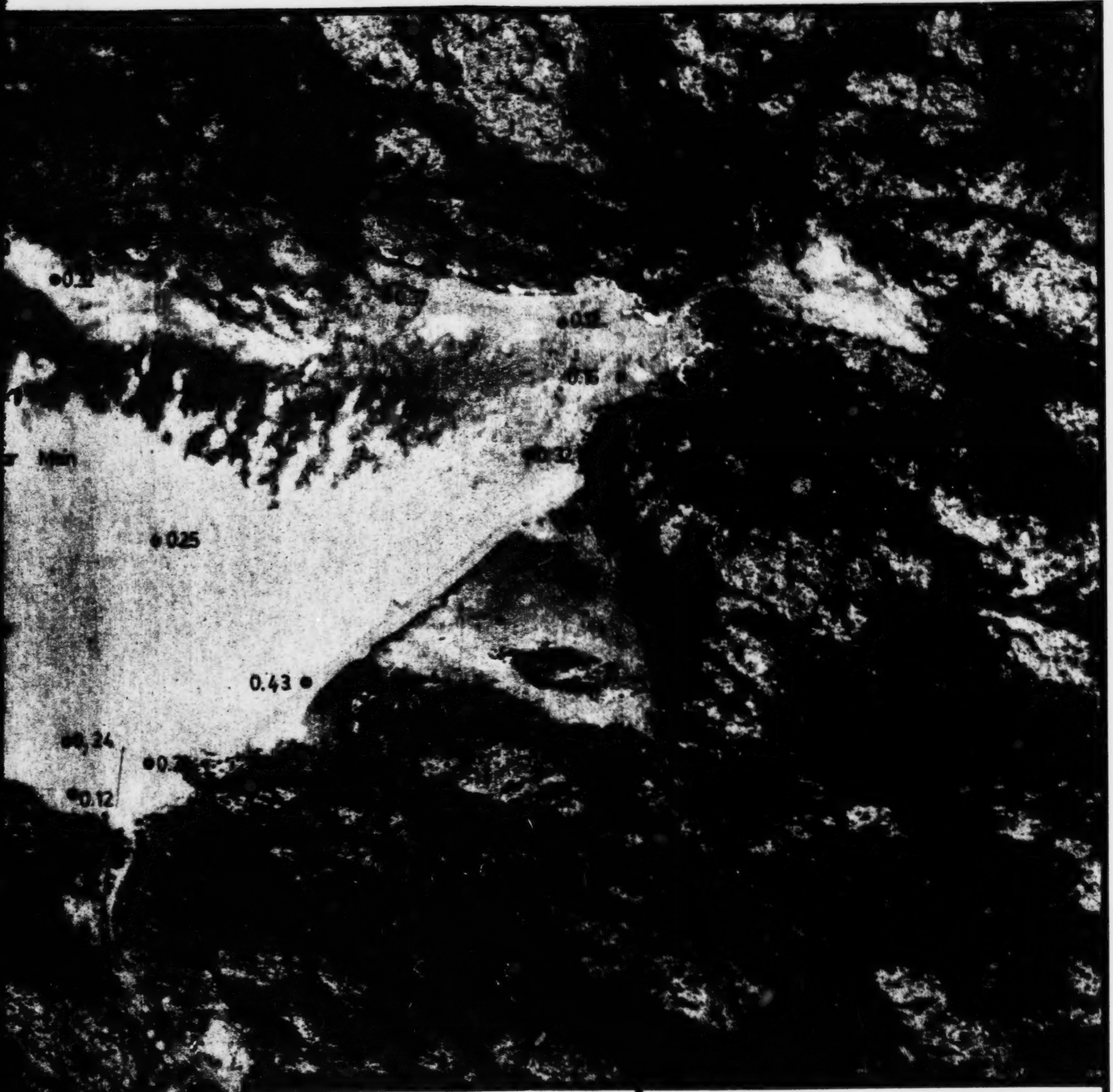
1 mR/hr = 8.7 μGy/hr

TABLE 3.16: GUNNAR MAIN AND LANGLEY BAY TAILINGS SITES SPOT GAMMA READINGS (mR/hr)

Site No.	Dec	May	June	July
1	0.26	0.34	0.40	0.36
2	0.23	0.30	0.32	0.31
3	0.24	0.25	0.30	0.31
4	NA	0.29	0.34	0.40
5	0.24	0.30	0.30	0.35
6	NA	0.44	0.48	0.43
7	0.32	0.39	0.45	0.46
8	0.12	0.24	0.42	0.45
9	0.23	0.25	0.28	0.32
10	0.20	0.21	0.22	0.26
11	0.22	0.26	0.34	0.30
12	0.14	0.19	0.24	0.24
13	0.30	0.13	0.50	0.50

1 mR/h = 8.7 μGy/hr


0.23
0.32
0.12
0.27
Gunnar Main
0.26
0.2
0.1


0.32
0.32
0.16
0.32
Main
0.25
0.43
0.24
0.12

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ATMOSPHERIC STUDIES

GAMMA LEVELS (1m height) mR/h

NATIONAL URANIUM TAILINGS PROGRAM

GUNNAR FIELD STUDY

SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE	DRAWN BY	FIG. 3.7
DATE	APPROVED BY	

Figure 3.7

TABLE 3.17: ROCK WASTE PILE - GAMMA SURVEY (uR/hr)

Setup No. 1: Horizontal Control Point No. 25 (1000 N and 5000 E)
Sighted in on Horizontal Control Point No. 26 - Smoke Stack on West Side of Open Pit by Shop (0° - 00')

Horizontal Angle	Vertical Angle	Rod Reading Lower	Rod Reading Middle	Rod Reading Upper	1-m Reading (ur/hr)	0.2-m Reading (ur/hr)
0°-30' right	0°- 0'	9.52	9.98	10.41	70-110	70-100
15°-20' left	0°- 0'	10.26	10.71	11.16	70- 90	70- 90
15°- 0' left	1°-50'down	8.89	9.70	10.57	120-100	90-100
29°-45' left	1°-50'down	7.85	8.66	9.46	80-100	120-160
29°-45' left	1°-50'down	7.21	7.62	8.03	100-130	100-120
44°- 5' left	1°-50'down	6.82	7.22	7.62	100-140	120-150
44°- 5' left	1°-50'down	6.37	7.18	7.99	100-130	100-120
59°-45' left	1°-50'down	4.58	5.44	6.30	120-140	220-260
59°-45' left	1°-50'down	5.83	6.30	6.76	90-120	70-100
74°-55' left	1°-50'down	4.60	5.07	5.54	200-240	189-210
74°-15' left	1°-50'down	2.50	3.44	4.36	100-140	80-110
74°-40' left	1°-50'down	1.88	3.21	4.59	140-160	160-200
74°-15' left	1°- 0'down	4.73	6.54	8.38	90-110	80-100
74°-20' left	1°- 0'down	2.70	4.89	7.09	30- 50	30- 50
14°-20' left	1°- 0'down	5.59	8.52	11.39	40- 70	40- 60
90°- 0' left	0°-27 1/2up	6.54	8.80	11.10	120-160	260-300
90°-25' left	0°-17'up	7.18	9.10	11.02	60-100	70-100
90°-20' left	0°-07'up	7.00	8.50	9.99	370-410	430-470
90°-20' left	0°-08'up	6.59	7.64	8.70	70-100	70-100
92°-30' left	0°-02'up	5.30	5.91	6.51	40- 70	50- 80
104°-55' left	0°-00'	2.91	3.52	4.09	80-110	90-130
105°-15' left	0°-00'	1.42	2.41	3.42	60- 80	50- 60
105°-15' left	1°-16'up	6.78	6.29	9.78	100-130	90-120
105°-20' left	1°- 0'up	7.78	9.62	11.53	140-180	140-180
119°-50' left	1°-28'up	6.05	7.40	8.71	240-280	280-320
					top of pile of smaller debris	
120°-15' left	1°-28'up	2.12	3.06	4.00	330-360	510-560
120°-10' left	1°-28'up	3.07	3.63	4.20	430-470	480-530
134°-50' left	2°-10'up	5.12	5.67	6.23	220-260	260-300

TABLE 3.17: ROCK WASTE PILE - GAMMA SURVEY (uR/hr) (cont'd)

Setup No. 2: At Point at Far End of Waste Rock Pile (528.847 N, 4744.752 E)
Sighted on Smokestack (0° - 00')

Horizontal Angle	Vertical Angle	Rod Reading			1-m Reading (ur/hr)	0.2-m Reading (ur/hr)
		Lower	Middle	Upper		
75°-00' left	2°-08'down	2.26	3.10	3.95	60- 80	70- 90
60°-00' left	2°-08'down	3.82	4.35	4.83	50- 70	30- 50
60°-00' left	2°-08'down	3.30	4.21	5.10	90-120	80-100
59°-45' left	2°-08'down	2.95	4.28	5.59	130-160	120-150
45°-00' left	1°-26'down	3.80	5.59	7.38	150-180	170-210
45°-00' left	1°-26'down	1.98	3.40	4.78	120-150	160-190
44°-45' left	1°-26'down	4.69	5.66	6.63	90-120	90-120
45°-00' left	1°-26'down	4.08	4.62	5.17	130-160	120-160
30°-00' left	1°-26'down	3.19	3.73	4.27	110-140	90-110
30°-00' left	1°-08'down	3.02	4.05	5.07	120-160	150-180
29°-45' left	0°-36'up	9.13	10.62	12.12	220-260	440-500
29°-45' left	0°-36'up	8.40	10.34	12.28	140-180	210-250
30°-00' left	0°-38'up	5.50	7.90	10.29	60- 80	70- 90
15°-00' left	0°-20'down	0.77	3.00	5.28	120-150	110-140
15°-00' left	0°-20'down	5.29	8.03	9.76	120-160	120-140
15°-00' left	0°-20'down	6.65	7.94	9.21	70-100	50- 80
15°-00' left	0°-20'down	6.74	7.55	8.36	50- 80	50- 60
14°-45' left	0°-20'down	6.02	6.50	6.98	100-140	120-160
0°-20' left	0°-00'	7.66	8.14	8.60	60- 80	60- 80
0°-20' left	0°-00'	8.45	9.36	10.30	40- 60	40- 60
0°-15' right	0°-00'	8.44	9.80	11.16	60- 80	70- 90
0°-15' right	0°-00'	6.92	8.73	10.54	140-290	200-240
0°-00'	0°-00'	7.05	9.28	11.50	110-140	80- 10
14°-20' right	1°-30'down	2.18	4.06	5.98	70- 90	70- 90
14°-20' right	1°-30'down	1.60	3.05	4.51	40- 60	60- 70
14°-15' right	1°-30'down	2.65	3.67	4.71	40- 60	50- 70
14°-20' right	1°-30'down	5.34	5.89	6.45	70- 90	60- 80
30°-15' right	1°-30'down	5.25	5.73	6.22	60- 80	70-100
30°-15' right	1°-30'down	3.93	4.85	5.75	40- 60	30- 50
30°-15' right	1°-30'down	4.70	6.00	7.31	70-100	80- 90
30°-00' right	1°-30'down	6.30	8.02	9.75	50- 70	60- 70
45°-00' right	2°-22'down	5.40	8.07	10.72	60- 80	70- 80
45°-00' right	2°-22'down	5.50	7.78	10.00	60- 90	60- 70
45°-00' right	2°-22'down	4.66	6.42	8.18	50- 80	50- 80
45°-00' right	2°-22'down	3.15	4.48	5.80	70- 90	70- 90
45°-00' right	2°-22'down	3.51	4.39	5.26	140-160	280-320
45°-15' right	2°-22'down	4.05	4.58	5.12	60- 80	80- 00
60°-00' right	2°-22'down	3.85	4.35	4.82	60- 80	70- 90
60°-15' right	2°-22'down	4.75	5.70	6.62	90-110	120-140
60°- 0' right	2°-22'down	5.05	6.45	7.86	90-110	100-120
60°- 0' right	2°-22'down	6.38	8.18	10.00	50- 70	60- 90
60°-15' right	2°-53'down	4.38	6.60	8.85	30- 70	60- 70
75°-15' right	2°-53'down	4.49	6.19	7.89	70- 90	80- 00
75°-20' right	2°-53'down	2.72	3.98	5.22	40- 60	30- 50
75°-30' right	2°-53'down	1.51	2.28	3.06	160-190	120-160
	At transit location				80-110	120-140
	Transit 5.3' above ground					

Notes:

1. The angle from the smokestack (Point No. 26) when setup on Point No. 25 turned to the temporary setup at the south end of the Waste Rock Pile was 42° 32'.

2. From the setup at the south end of the Waste Rock Pile the angle from Point No. 25 to the smokestack was 100° 00'.

TABLE 3.18: RESULTS OF ON-SOURCE GAMMA DOSIMETER MEASUREMENTS
(Exposure Rate µR/h)
(replicates in brackets)

	Surface Data Period		1-Metre Data Period	
Site No.	Dec - Apr	May - August	Dec - Apr	May - August
M1	NA	460	180	450
M2	320	390	120 (120)	380 (390)
M3	420	460	140 (130)	360 (380)
M4	not sampled	560	not sampled	470
M5	340 (350)	430*	210	390
M6	600 (600)**	660 (670)	320	570 (600)
M7	370 (360)	510	190	470
M8	390	560	160	470 (480)
M9	440	280	130	310 (310)
M10	330	460	210	310 (310)
M11	570	510 (450)	320 (330)	410
M12	390	270	NA	300 (300)
M13	not sampled	440 (420)	not sampled	480 (470)**
W	not sampled	150 (150)	not sampled	150

Transportation 5 (5,4)

* note dosimeter found displaced from original location
** stake had fallen over and gamma dosimeters were on the surface

1 µR/h = 8.7 µGy/hr

TABLE 3.19: RESULTS OF AMBIENT SITE GAMMA DOSIMETER DATA
(Exposure Rate μR/h)
(replicates in brackets)

Surface Data

Site No.	Period May - June	 June - July
A1	22.6(27.4)	31.1(32.4)
2	20.3(20.0)	27.8
3	19.1(18.2)	27.0(26.3)
4	36.3(40.6) (56.1)	47.8(47.1) (42.2, 44.0)
5	15.7(14.7)	23.4(20.8)
6	753 (875)	502 (514)
7	22.9(21.4)	29.8(30.2)*
8	11.6(11.0)	20.3(18.5)
9	10.3(11.5)	16.3
10	15.0(14.8)	19.9(20.6)
11	6.9(8.4)	16.8(17.6)
12	13.0(14.0)	22.8(22.4)
13	11.8(13.6)	28.0(27.1)

* dosimeters found on ground

1 μR/h = 8.7 μGy/h

3.9.5 Dust Measurement Data

The results of calculations and analyses to determine the total amount of dust in the snow-core are provided in Table 3.20. Additional analyses of these samples included microscopic analysis of the particles in a 50 ml aliquot of the water sample. Data from these analyses are provided in Table 3.21.

Both knolls were approximately 5 m^2 in size when sampling was conducted on March 25, 1985. At the time of sampling, a sample of the loose surface material from both knolls was collected. This was subjected to chemical analysis of the minus 400 mesh fraction. The results of this analysis are given in Table 3.22.

3.10 Discussion

The field measurement program at Gunnar covered the period from early December 1984 to September 30, 1985. Different measurements were conducted over this time and 5 site visits were utilized to collect data. The sampling program durations are outlined in Figure 3.9. A chronology of site station events is provided in Chapter 15. This section of the report discusses the data and presents comments on the values collected.

3.10.1 Meteorological Data

The two major radiological contaminant sources on the tailings, radon and dust are released at rates that are influenced by the weather. Pertinent weather parameters for radon are rainfall, and thus moisture levels in the tailings, temperature and barometric pressure. Frozen tailings are known to attenuate radon flux rates as are high moisture levels. Dust releases are also influenced by temperature (frozen) and moisture levels but are chiefly influenced by wind velocity. Table 3.23 summarizes some of the pertinent meteorological data collected at the Gunnar Main tower location.

TABLE 3.20: SUMMARY OF SNOW CORE DATA

Sample Site	Snow Depth (cm)	Snow Volume (L)	Water Volume (L)	Ratio L Snow: L H_2O	Dust (µg/mL)	Total Dust* (mg) in 315 cm^2	Total Dry Dust (mg/cm^2 of surface)
K1-10S	71	23.02	4.35	5.3	0.23(1.8)	1000	3.18
10E	41	13.30	4.20	3.2	5.9	24780	78.7
10W	41	13.30	3.79	3.5	24.5	92855	29.5
15N	28	9.08	2.30	4.0	8.2	18860	6.0
20S	41	13.30	2.55	5.2	1.9	4845	15.4
20E	61	19.78	4.23	4.7	10.6	44838	142.3
20W	58	18.81	4.00	4.7	2.7 (5.9)	10800	34.3
30E	41	13.30	3.45	3.9	2.4	8280	26.3
30W	71	23.02	4.45	5.2	4.5	20025	63.8
K2-10N	15	4.86	1.48	3.3	17.0	25160	80
10S	33	10.70	2.23	4.8	3.0	6690	21.2
10E	28	9.08	2.60	3.5	13.9	36140	114.8
10W	15	4.86	1.32	3.7	13.2	17424	55.3
20E	33	10.70	2.74	3.9	6.3	17262	54.8
20W	61	19.78	4.35	4.5	8.7	37845	120
30E	76	24.65	6.70	3.7	3.3(3.7)	22110	70.2
30W	71	23.02	3.67	6.3	5.7	20919	66.4

20 cm dia core = 315 cm^2

TABLE 3.21: MICROSCOPIC ANALYSIS OF SNOW CORE DUST SAMPLES

Sample No.	Dilution	Magnification	Size Range* (μm)	No. of Particles**	Average Diameter*** (μm)	Size of Particles (μm) (μ) (length x width)
K1-reference Material from the surface of Knoll #1	1/100	775x	5-40	13	14.4	(20x20), (20x10), (30x15), (10x10)^{3}, (40x18), (15x15), (5x5)^{2}, (30x30), (10x15), (3x3)
K2-reference Material from the surface of Knoll #2	1/100	775x	5-30	9	9.3	(5x10)^{2}, (5x5)^{4}, (7x5), (15x10), (40x20)
B1	undiluted	775x		0		
K1-15-N	1/20	775x	3-40	24	8.4	(10x5)^{6}, (5x5)^{7}, (3x3)^{5}, (10x10)^{2}, (30x15)^{2}, (40x20), (10x20)
K1-10-SR	1/10	775x	5-30	16	9.0	(12x7), (5x10)^{3}, (15x10)^{3}, (5x5)^{3}, (10x10), (20x5), (7x5)^{2}, (3x3), (30x15)
K1-10-S	1/10	775x	5-65	20	8.2	(5x7)^{2}, (12x5), (8x8)^{2}, (5x10)^{2}, (10x8), (5x5)^{4}, (10x10), (30x15), (15x15), (20x10), (15x5), (3x5)^{2}, (3x3)
K1-10-E	1/20	775x	5-20	22	7.3	(5x10)^{4}, (5x8)^{3}, (5x5)^{7}, (20x20), (3x3)^{3}, (10x15), (10x8), (10x10), (15x15)
K1-10-W	1/20	775x	3-32	32	5.0	(10x10)^{6}, (20x15), (20x10), (5x10)^{3}, (5x5)^{4}, (15x10), (3x3)^{14}, (8x5), (15x5)
K1-20-S	1/20	775x	3-55	24	7.9	(15x10), (25x15), (5x10)^{3}, (10x10)^{2}, (5x5)^{8}, (30x40), (15x20), (3x3)^{7}
K1-20-WR	1/10	775x	5-15	8	7.4	(5x3)^{2}, (10x10), (5x5)^{2}, (5x7), (10x15)^{2}
K-20-E	1/20	775x	3-40	17	6.7	(20x10), (5x5)^{11}, (10x10), (5x10)^{2}, (15x5), (3x3)
K1-20-W	1/20	775x	7-40	20	9.5	(20x20)^{2}, (5x5)^{5}, (10x5)^{6}, (10x10)^{6}, (15x25)
K1-30-W	1/10	775x	3-40	6	11.7	(5x5)^{2}, (20x35), (10x10)^{2}, (15x10)
K1-30-E	1/20	775x	3-40	13	10.0	(10x10)^{5}, (5x5), (3x3), (15x10)^{3}, (5x5)^{2}, (15x15)
Gita ''	undiluted	775x	10	7	7.9	(10x10)^{4}, (5x5)^{3}
K2-10-E	1/10	775x	5-40	14	12.9	(10x5)^{2}, (5x5)^{4}, (20x15), (50x40), (30x30), (15x10), (15x15), (10x10)^{2}, (5x5)
K2-10-W	1/20	775x	5-30	13	11.2	(20x15), (5x5)^{2}, (10x5)^{4}, (15x5), (10x10)^{2}, (15x10), (30x15)^{2}
K2-15-N Bottom	1/10	775x	5-40	20	9.6	(10x5)^{3}, (5x5)^{8}, (15x5), (15x15), (10x10)^{3}, (30x10), (10x15), (15x20), (30x20)
K2-15-S Top	1/10	775x	3-40	14	7.1	(5x5)^{5}, (10x10)^{4}, (10x15), (10x5)^{3}, (15x5)
K2-20-E	1/10	775x	5-45	3	22.5	(10x5), (15x20), (40x45)
K2-20-W	1/20	775x	3-45	19	8.7	(10x5)2, (15x10), (10x10)^{2}, (30x40), (5x5)^{11}, (25x10), (15x5)
K2-30-E	1/10	775x	8-30	8	10.0	(10x5)^{4}, (20x15), (20x10), (5x5), (15x10)
K2-30-W	1/10	775x	3-40	13	8.5	(10x5)^{3}, (5x5)^{7}, (30x20), (10x15), (20x10)
K2-30-E 2nd	1/20	775x	5-30	5	11.0	(10x10)^{3}, (10x15)^{2}

* size range smallest to largest particles on photo
** number of particles touching diagonal line across photo
***average diameter taken as average lengths and widths from each particles on diagonal line

TABLE 3.22: ANALYSIS OF MINUS 400 MESH MATERIAL FROM EXPOSED TAILINGS SURFACES (March 25, 1985)

Major Constituents		
SO_4, solids	%	0.12
SiO_2, gravimet	%	46.9
Radionuclides		
Pb 210, total	Bq/g	18
Pa 210, total	Bq/g	18
Ra 226, total	Bq/g	20
Th 230, total	Bq/g	20
U, total	µg/g	1750

FIGURE 3.9: OBSERVING PERIODS FOR DIFFERENT ATMOSPHERIC COMPONENT PROGRAMS

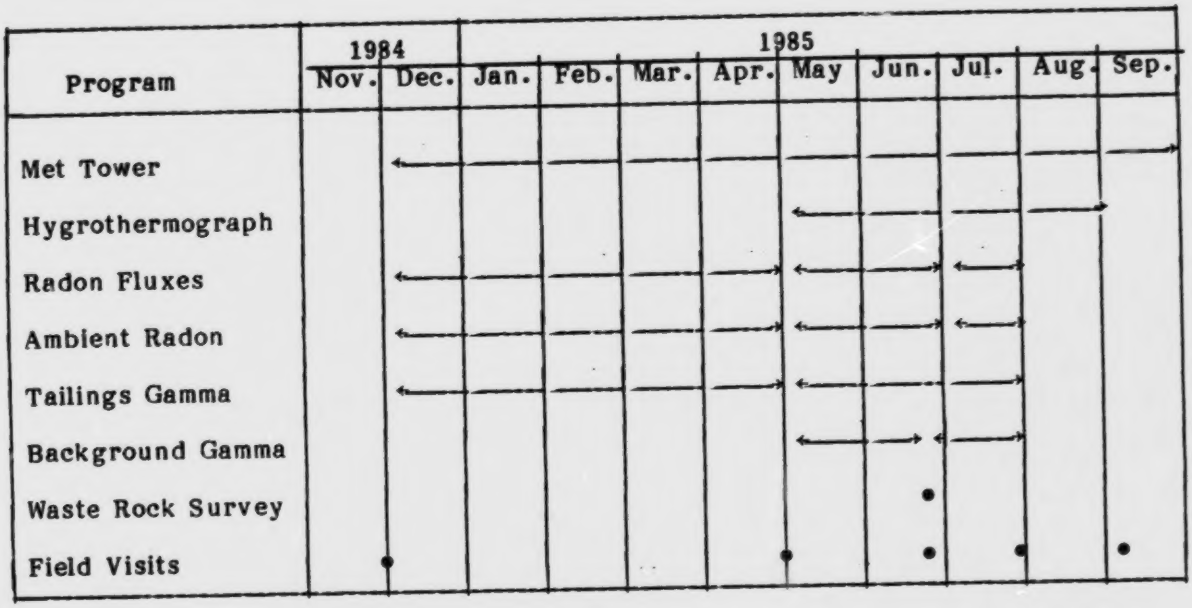

TABLE 3.23: SIGNIFICANT MONTHLY METEOROLOGICAL VALUES

Month	Data Capture (%)	10m Temperature (°C)		Maximum Wind		No. of Days With Winds > 20 km/hr	No. of Days With Rain	Rain Depth (mm)
		Extreme Minimum	Extreme Maximum	Speed (km/hr)	Direction (°)			
Dec. '84	*	-50	+2	36	90°	18	NA	-
Jan. '85	100	-42.6	+6.1	42.9	104°	12	NA	-
Feb. '85	99	-42.6	3.7	49.9	90°	18	NA	-
Mar. '85	98	-31.6	14.3	37.4	80°	20	NA	-
Apr. '85	77	-16.7	17.8	48.2	38	20 out of 23	NA	-
May '85	99	- 3.4	29.6	44.1	89	26	4	2.8
Jun. '85	99	- 0.6	35.8	34.7	341	21	6	38.3
Jul. '85	99	4.5	35.5	37.2	285	26	11	39.1
Aug. '85	100	3.3	33.9	33.5	113	21	11	52.6
Sep. '85	100	- 4.9	26.0	44.7	316	22	9	26.7

* - Tower started working Dec. 9, 1984, 2130 GMT, Data reported is after tower moved.

NA - Not available, instrument out of service until May 3, 1985.

+ - One week of data loss due to processing error at receiving station.

The data suggests that mean temperatures (maximum minus minimum) will be above zero, or the freezing point, for at least April through September. One would expect that site conditions would be conducive to higher releases during this period. However, precipitation levels increase from May through August suggesting that this could attenuate dust release levels. Also it was noted that some snow remained on Gunnar Main and Langley Bay on the May 3 field trip. Ground below the tailings surface was also still frozen at this time, and extensive snow was still present off the tailings areas. Tailings were damp in June during the site visit.

Winds in the range of 15-20 kph at the surface are generally thought to be sufficient to cause saltation activity and the onset of dust emissions. Greater than 50% of the days in most months recorded some 10 m winds in excess of 20 kph. It was noticeable in the winter that wind erosion of the surface was occurring as the snow was streaked with dust from the hummocks that became exposed. It is possible that ice crystals acted as the saltating media in the winter and these may increase the extent of erosion. This situation is at odds with the conventional wisdom that assumes that when the surface is frozen no fugitive emissions occur. Spring conditions indicated that high easterly winds could cause dust clouds up to 10-15 m above the tailings. These were particularly evident with winds over 30 kph. Many of the mats on Gunnar Main were covered with blown dust during the June/July site visits.

Highest winds in the winter generally occurred from the east and its effect is shown by the high dust levels noted in the snowpack west of the two exposed knolls used for sampling.

3.10.2 Radon Data

3.10.2.1 Radon Flux

Tables 3.12 and 3.13 present the summarized tailings radon flux data.

Table 3.12 gives the estimation of the radon fluxes and the bulk diffusion constants based on the 'can' technique. Although the design of the measurements was based on 3 cans of different heights being assigned to a location, at some locations this was not possible and only two readings were used to determine the diffusion coefficient. The anomalous readings recorded for the third sampler is believed to be due primarily to incomplete sealing around the top of the cans.

The values for the diffusion coefficient tend, as expected, to be larger in spring and summer than in winter. In calculating the bulk diffusion constants for each season all values were used in determining the best estimate although it is recognized that the value for Site 8 (summer) is smaller than expected. The averages of the bulk diffusion constants for each season however do follow the expected pattern:

Bulk Diffusion Constant (cm^2/s)	Season
9.1E-4	Winter
2.6E-2	Spring
7.7E-2	Summer

These values are consistent with those reported in the literature, for example, Tanner (1964) gives a value of 8E-3 for most soils and Leach (1982) a value of 2E-2.

The values of the radon flux as estimated from the 'mat' technique are given in Table 3.13. These were calculated using the values of the diffusion constants as derived above. Although there was some concern that the high radon measurements were saturating the detectors, the short term grab samples gave results similar to those of the longer term measurements and hence gave assurance that no gross error was being made. Except where field problems were noted the results demonstrated good internal consistency and with the exception of Site 8 (summer) very good agreement was obtained between the fluxes measured by the can and mat techniques.

3.10.2.2 Ambient Radon Levels

The seasonal flux rates shown from can and mat measurements are reflected in the ambient radon levels determined by season. Table 3.14 presents the seasonal summary data and illustrates a consistent increasing trend in radon levels at all sites.

The highest radon flux data was recorded at site A6. Gamma dosimeter data indicates anomalies at this site. Indications are that some tailings spillage may have occurred at this location.

3.10.2.3 Radon Data from Waste Rock Pile

Mat data for 5 samplers under a large mat on the waste rock pile is summarized in Table 3.24. No determination of flux rates can be made since cans were not installed on this surface. The data illustrates several features of the waste rock however:

- generally the radon levels are significantly lower than those on the main tailings, 200-400 pCi/L versus 20,000-40,000 pCi/L on the tailings. This is not unexpected since the mineralization would be anticipated to be much lower.

- the value are all within a factor of two. While standard deviations for the data are in the order of 10 percent (derived from counting statistics) the low range of values illustrates that few problems were experienced with the mat technique providing a representative level.

TABLE 3.24: WASTE ROCK RADON MAT DATA (pCi/L)

Site No.	Period April-June	June-August
Center	254	222
1mN	199	290
1mS	249	224
0.5mE	256	221
0.5mW	361	223

1 Bq = 27 pCi

3.10.3 Gamma Measurements

3.10.3.1 Spot Gamma

As anticipated a slight increase in gamma readings on the tailings was recorded between winter and summer.

Ambient site spot levels did not change dramatically. Relatively consistent gamma spot readings on Gunnar Main were recorded during the winter campaign. Deviations were most noticeable at the edges of the area.

The highest spot-gamma reading was measured at ambient site A6 (which also had the highest ambient radon reading from the winter period), a value of 0.65 mR/h at the 1-m level. These high readings probably result from the presence of small diameter tailings washed down from the Gunnar Main tailings.

Material composing the waste rock pile was of too heterogenous a nature for consistent spot gamma readings. In at least one instance where the 0.2-m reading was considerably higher than the 1-m reading, the cause was found to be the close proximity of a 0.2+ mR/h source. During the detailed gamma survey on the waste rock pile, 73 measurement locations were used and only 10% of these recorded 1-m values greater than 0.1 mR/h.

3.10.3.2 Tailings Gamma Dosimeters

Winter tailings field exposures were typically 1000-2000 mR at ground level while exposures at 1 metre range from 400-800 mR. There is good consistency between exposures measured by 2 dosimeters at the same site. Transportation dosimeters indicated very low exposures. The irradiated decay dosimeters exposures at readout averaged only 4% less than their calibration values demonstrating minimal decay. The exposure rates varied between 100-300 μR/h at 1 metre above ground rising to between 300-600 μR/h at ground level.

Field exposure rates for the second set of tailings dosimeters varied from 300 to 700 μR/h near the surface of the tailings and 300 to 600 μR/h at a height of one metre above the surface. These rates were generally only slightly higher than those measured for the winter period as the shielding provided due to the ice, snow and water cover would be minimal. This would also be consistent with the small differences of the exposure rates near the surface and at a height of one metre. Good consistency was also found between the exposure rates measured by replicate detectors.

Waste rock pile levels were approximately 150 μR/h regardless of height.

3.10.3.3 Ambient Gamma Dosimeters

Normal background gamma dose rates in the study area are expected to range between 8 - 15 μR/h. Of the 14 sites surveyed in the spring, 9 sites exhibited field strengths within this range or slightly higher, less than 20 μR/h. Two sites demonstrated marginally elevated readings, sites VT-7 (22 μR/h) and site VT-1 (25 μR/h). The fields at sites VT-4 (38 μR/h) and site VT-S8 (44 μR/h) were significantly greater than expected and could be due either being located near or over a small pocket of uranium or of tailings. The field at location VT-6 was very high (810 μR/h) suggesting that the location was heavily contaminated with tailings.

The fields at the location where the dosimeters were placed for the second (summer) period appear to be slightly higher (~ 25%) than those measured during the spring period. This is not too surprising as during this period any shielding provided by snow or water would tend to be minimized and the height of the dosimeters may have varied somewhat. Of the 14 sites surveyed, only 2 sites are significantly above expected range, ST-4 (47 μR/h replicate 43 μR/h), ST-6 (510 μR/h), and the other sites demonstrating values less than 30 μR/h. The elevated fields at site ST-4 are most probably due to small pockets of ore or tailings near the detector while the detector at site ST-6 was probably located near a large fugitive tailings area.

Good repeatibility is evidenced by the data presented in Table 3.18.

3.10.4 Dust Data

The cursory dust survey revealed several interesting facets of the fugitive dust emissions during the winter. Significant qualities of dust were found in the snowcores suggesting that wind erosion continues year round. Predominant burdens wre recorded in the east and west directions however, a limited number of samples were collected and this could bias the distribution. The wind data and the precipitation (snowfall from Uranium City) would have to be combined to test the hypothesis of predominant directions. Some irregularities in the anticipated distribution of dust in the snowcore may be due to the varying depth of snow in different directions.

The size distributions established by microscoic examination reveals several interesting facts about the dust movement:

- o particles ranged from 3-65 µm in size;
- o the predominant size range appears to be 7-10 µm, this is also the high activity fraction; and
- o no particles under 3 um were noted suggesting that they become airborne.

Summer observations suggest considerable saltation movement of particles across the surface. The mats become covered with up to 3 cm of sand. Sand is generally larger than 75 µm in diameter and difficult to make airborne. Given the size range of the particles found in the snowpack, one would suspect ice and snow to initiate saltation in the winter and predominantly fine material is eroded during the winter. This suggests that, in areas with low snowfall, or long periods of cold weather preceding appreciable snow cover fugitive dust emissions could be significant. At Gunnar, the emissions may be reduced due to the limited open area available for saltation.

The limited data collected during the field programme precludes a strict comparison of measured levels with predicted levels based upon any accepted models of wind erosion potential; nor can the data be used to simply back calculate an emission rate since the precipitation and wind history are not well defined. Source term estimates are available if one applies the accepted models. An open area wind erosion model was chosen for the NUTP probabilistic model demonstration project (Beak, 1986) and this will be used for this project too. Based on the work of Cowherd et al., 1979.

$$E_{OA} = 0.38\ (e/0.184)\ (S/15)\ (f/25)/\ \left(\frac{PE}{50}\right)^2$$

were E_{OA} = emission rate in kg per m^2 per year of exposed land,

e = soil erodibility or potential annual soil loss rate for a wide, unsheltered, isolated field with a bare, smooth surface in tonnes per km^2 per year

S = silt content of eroding surface in %,

f = percentage of the time that wind velocity measured 0.3 m above the surface exceeds the nominal wind erosion threshold value of 19.4 km per hour,

PE = Thornthwaite's Precipitation-Evaporation Index.

Thornthwaite's Precipitation-Evaporation Index (PE) is a measure of the annual or seasonal surface moisture function and is used to adjust emission rates reflecting normal retained moisture.

The parameters of the equation can be interpreted from field data and information provided by NRCC (1982). Erodibility can be determined from BBT soils data, Volume 4 and interpretation of NRCC (1982). The BBT data indicates that the surface material ranges from silty clay to silty clay loam and the erodibility index should range from 0.17 to 0.38 T/km^2 a^1. The annual PE Index from NRCC (1982) is 40. The percentage of winds above 19.4 kph is 15-16% from historical Uranium City data. The silt content, defined as minus 200 mesh or less than 74 µm ranges from 7-98% on the surface samples, and averages 33% for the 12 surface samples.

These values suggest an erosion rate of 1.2 kg/m^2/year would be possible on the Gunnar site. The actual occurrence of this level would depend on many factors which were not determined during this study.

3.11 Bibliography

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CHAPTER 12

Basic Programme for Meteorological Data Retrieval

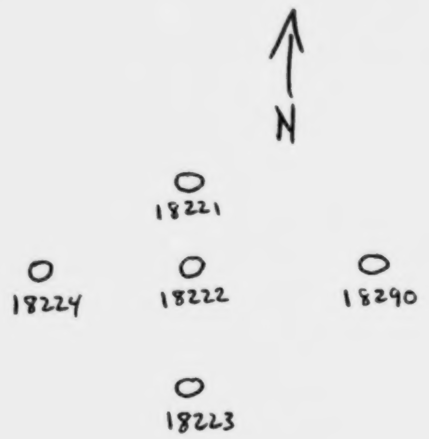
```
10 ' THIS IS A PROGRAM TO READ AND DISPLAY  THE GUNNAR DATA DISKETTE.
20 ' NICK NICOLICHUK  JULY 29, 1985
30 OPTION BASE 1
40 CLS  : FOR I=1 TO 5 : PRINT " " : NEXT I
50 OPEN "GUNNAR" AS #2 LEN=20
60 FIELD 2,2 AS WINDSPEED$, 2 AS WINDDIRECTION$, 2 AS ACCUMPRECIP$,
70 PRINT "PLEASE ENTER THE JULIAN DAY FOR THE DATA SET YOU WANT ";
80 INPUT DAY
90 PRINT " "
100 PRINT "PLEASE ENTER THE HOUR FOR THE DATA SET YOU WANT ";
110 INPUT HOUR
120 PRINT " "
130 WHERE1%=(DAY-1)*48 + HOUR*2 + 1
140 WHERE2%=(DAY-1)*48 + HOUR*2 + 2
150 IF WHERE1% < 1 THEN GOTO 70
160 IF WHERE1% >365*48 + 23*2 +2 THEN GOTO 70
170 GET #2,WHERE1% : ' THIS IS THE DATA FOR ON THE HOUR
180 PRINT USING "#####";DAY;
190 PRINT USING "####";HOUR;
200 PRINT USING "######.#";CVI(WINDSPEED$)/10;
210 PRINT USING "#######.#";CVI(WINDDIRECTION$)/10;
220 PRINT USING "#######.#";CVI(ACCUMPRECIP$)/10;
230 PRINT USING "#####.#";CVI(INCREPRECIP$)/10;
240 PRINT USING "#####.#";CVI(BATTERY$)/10;
250 PRINT USING "#####.#";CVI(TEMP2METER$)/10;
260 PRINT USING "#####.#";CVI(TEMP10METER$)/10;
270 PRINT USING "####.##";CVI(RAD$)/100
280 GET #2,WHERE2% : ' THIS IS THE DATA FOR THIRTY MINUTES AFTER THE HOUR.
290 PRINT "         ";
300 PRINT USING "######.#";CVI(WINDSPEED$)/10;
310 PRINT USING "#######.#";CVI(WINDDIRECTION$)/10;
320 PRINT USING "#######.#";CVI(ACCUMPRECIP$)/10;
330 PRINT USING "#####.#";CVI(INCREPRECIP$)/10;
340 PRINT USING "#####.#";CVI(BATTERY$)/10;
350 PRINT USING "#####.#";CVI(TEMP2METER$)/10;
360 PRINT USING "#####.#";CVI(TEMP10METER$)/10;
370 PRINT USING "####.##";CVI(RAD$)/100
380 GOTO 70
390 END
400 CLOSE
```

CHAPTER 13

TERRADEX Data

THM

	SERIAL NUMBER	RADON EXP. RATE (PCI/LITER)	STD. DEV. PCT.	FIELD NOTES AND DATA
WRP	18221	47.99	10.8	
WRP	18222	65.35	9.3	
WRP	18223	101.76	7.4	
WRP	18224	45.19	11.2	
M6	18225	24440.16	2.4	
A4	18226	3.86	27.4	
A14	18227	10.36	16.6	
A3	18228	5.39	18.5	
A2	18229	5.39	16.5	
A1	18230	5.59	20.7	
CS8	18231	6554.17	4.7	
M8	18232	59149.52	1.6	
CT8	18233	6210.54	4.9	
M8	18234	57570.75	1.6	
M9	18235	50192.04	1.5	
A10	18241	7.25	19.9	
A12	18242	10.05	16.8	
A1	18243	6.36	19.9	
~~A13~~ A13	18244	7.32	19.1	
A5	18245	12.48	14.7	
M5	18247	19223.48	2.8	
M3	18266	36356.55	2.0	
M3	18267	39206.88	2.0	
CS3	18268	50450.30	1.7	
CM3	18269	32935.43	2.2	
M10	18286	19223.48	2.5	
M11	18287	73930.94	1.4	
M12	18288	27400.04	2.4	
M13	18289	30444.31	2.2	
WRP	18290	43.51	11.4	
A8	18291	9.27	17.1	
A9	18292	5.26	22.7	
A15	18293	5.33	20.7	
A7	18294	6.06	21.1	
A6	18295	23.97	10.6	
CT3	21395	42383.49	1.6	
M1	21396	36261.41	1.9	
M7	21397	24062.32	2.5	
M2	21398	31081.19	2.1	
M4	21399	28574.63	2.3	
CM8	21400	13320.43	3.2	
GCS8	23521	1547.38	5.2	
GM5	23522	13402.58	9.3	
GCM8	23523	2174.55	9.5	
GM8	23524	21211.30	7.4	
GM7	23525	13519.23	9.3	
GCT3	23526	20745.54	7.5	
GCM3	23527	17245.99	8.2	
GM3	23528	20529.09	7.5	
GCS3	23529	24591.95	6.9	



Placement of cups on WRP.

Installed June 24, '85
Retrieved July 27, '85

SERIAL NUMBER	RADON EXP. RATE (PCI/LITER)	STD. DEV. PCT.	FIELD NOTES AND DATA
GCTI 23530	1245.00	9.7	

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CONCORD SCIENTIFIC   08-12-85

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 EXP. RATE       DEV.    SERIAL
(PCI/LITER)      PCT.    NUMBER   FIELD NOTES AND DATA
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      3.36       27.4    18226
      5.26       22.7    18292
      6.06       21.1    18294
      6.33       20.7    18293
      6.69       20.7    18230
      6.86       19.9    18243
      7.26       19.9    18241
      7.82       19.1    18244
      8.39       18.5    18229
      8.39       18.5    18228
      9.27       17.1    18291
     10.08       16.3    18242
     10.36       16.5    18227
     12.48       14.7    18245
     23.97       10.6    18295
     43.51       11.4    18290
     45.19       11.2    18224
     47.99       10.8    18221
     65.35        9.3    18222
    101.76        7.4    18223
   1245.00        9.7    23530
   1547.38        5.2    23521
   2174.55        9.5    23523
   6210.54        4.9    18233
   6554.17        4.7    18231
  13320.43        3.2    21400
  13402.68        9.3    23522
  13519.23        9.3    23525
  17245.99        8.2    23527
  19223.46        2.8    18247
  19223.48        2.8    18236
  20629.09        7.5    23528
  20745.64        7.5    23526
  21211.36        7.4    23524
  24062.82        2.5    21397
  24440.16        2.4    18225
  24591.95        6.9    23529
  27400.04        2.4    18238
  28574.63        2.3    21399
  30444.51        2.2    18239
  31081.19        2.1    21398
  32935.43        2.2    18269
  36261.41        1.9    21396
  36365.38        2.0    18256
  39208.68        2.0    18267
  42363.49        1.8    21395
  56192.04        1.6    18235
  56460.86        1.7    18268
  57670.78        1.6    18234
  59149.52        1.6    18232
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CONCORD SCIENTIFIC   08-12-85

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(PCI/LITER)     PCT.   NUMBER  FIELD NOTES AND DATA
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 NUMBER  (PCI/LITER)      PCT.   FIELD NOTES AND DATA
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  18210        4.24       14.5
  18211        6.01       12.2
  18212        3.26       16.6
  18213        4.06       14.8
  18214        2.73       18.1
  18215        5.48       12.8
  18217    29559.09        1.8
  18218    34835.62        1.7
  18219    30670.39        1.8
  18220    30854.39        1.8
  18236    29859.09        1.8
  18237     1094.72        9.5
  18238     1044.96        9.8
  18239    34835.62        1.7
  18240    12938.58        2.6
  18246    27946.72        6.3
  18248    34028.05        6.2
  18249    31623.53        1.7
  18250    34835.62        1.7
  18251      479.21       10.5
  18252      287.50       13.6
  18253      235.33       14.7
  18254         .13       42.8
  18255        4.23       21.1
  18256        4.42       20.7
  18257        5.72       18.1
  18258        3.32       22.7
  18259        3.93       22.2
  18260        3.11       24.7
  18261        4.69       20.3
  18262        1.98       15.7
  18263        3.36       24.0
  18264        3.93       22.2
  18265        4.50       20.7
  18270     5950.45        8.5
  18271    62704.22        1.3
  18272    40254.53        1.5
  18273    53672.75        1.3
  18274    36420.76        1.6
  18275    42171.42        1.5
  18276    18910.71        2.3
  18277     3354.44        5.3
  18278    13934.18        2.7
  18279     7365.16        3.7
  18280     9952.95        3.2
  18281      249.09        9.8
  18282      199.25        9.8
  18283      254.84        8.7
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          RADON         STD.
SERIAL  EXP. RATE       DEV.
NUMBER  (PCI/LITER)     PCT.  FIELD NOTES AND DATA
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 18284      256.27       9.7
 18285      361.70       8.1
 21391   10955.03        7.3
 21392   23426.41        7.1
 21393   14218.56        9.1
 21394     2539.76       9.6
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CONCORD SCIENTIFIC 07-08-85

RADON EXP. RATE (PCI/LITER)	STD. DEV. PCT.	SERIAL NUMBER	FIELD NOTES AND DATA
.13	42.8	18254	
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2.73	15.1	18214	
2.82	17.9	18208	
3.11	24.7	18260	
3.26	16.6	18212	
3.35	16.4	18209	
3.36	24.0	18263	
3.82	22.7	18258	
3.93	22.2	18259	
3.93	22.2	18264	
4.06	14.8	18213	
4.23	21.1	18255	
4.24	14.5	18210	
4.42	20.7	18256	
4.50	20.7	18265	
4.69	20.3	18261	
5.48	12.8	18215	
5.72	18.1	18257	
6.01	12.2	18211	
199.25	9.3	18282	
235.83	14.7	18253	
249.09	9.8	18281	
254.84	8.7	18283	
256.27	9.7	18284	
287.50	13.6	18252	
361.70	8.1	18285	
479.21	10.5	18251	
1044.96	9.8	18238	
1094.72	9.5	18237	
2539.76	9.6	21394	
3354.44	5.3	18277	
5950.45	6.5	18270	
7365.16	3.7	18279	
9952.95	3.2	18280	
10955.03	7.3	21391	
12938.88	2.3	18240	
13934.18	2.7	18278	
14218.56	9.1	21393	
18910.71	2.3	18276	
23426.41	7.1	21392	
27946.72	6.8	18246	
29859.09	1.8	18217	
29859.09	1.8	18236	
30670.09	1.3	18219	
30854.39	1.8	18220	
31628.53	1.7	18249	
34028.05	6.2	18248	
34835.62	1.7	18218	
34835.62	1.7	18239	

RADON EXP. RATE (PCI/LITER)	STD. DEV. PCT.	SERIAL NUMBER	FIELD NOTES AND DATA
34835.62	1.7	18250	
36420.76	1.6	18274	
40254.53	1.5	18272	
42171.42	1.5	18275	
53672.75	1.3	18273	
62704.22	1.3	18271	

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                                  CONCORD SCIENTIFIC REREADS   07-18-85

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SERIAL  EXP. RATE         DEV.
NUMBER  (PCI/LITER)       PCT.  FIELD NOTES AND DATA
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 18251        14.58       11.4
 18252         9.26       14.4
 18253         6.72       16.6
 18255         4.52       14.8
 18270     5465.23         7.7
 18271    39512.16         1.6
 18273    55337.64         1.6
 18276    15625.20         2.5
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                                                                  PAGE  1
 CONCORD SCIENTIFIC REREADS   07-18-85

 RADON           STD.
 EXP. RATE       DEV.    SERIAL
(PCI/LITER)      PCT.    NUMBER  FIELD NOTES AND DATA
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      4.32       14.3     13255
      6.72       15.5     13253
      9.25       14.4     13252
     14.56       11.4     13251
   5463.23        7.7     13270
  15626.20        2.5     13276
  36337.04        1.5     13273
  39512.16        1.5     13271
```

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                                                          PAGE  1
                                 CONCORD SCIENTIFIC   NUTP   05-03-85

           RADON           STD.
SERIAL  EXP. RATE          DEV.
NUMBER  (PCI/LITER)        PCT.  FIELD NOTES AND DATA
------    ----------       ----  --------------------------------------

 18171          .40        21.1
 18172          .33        23.3
 18173          .56        17.0
 18174         2.27        17.1
 18175          .34        22.7
 18176         5.59         9.0
 18177          .46        19.1
 18178          .41        20.8
 18179          .32        23.3
 18180          .35        21.5
 18181          .94        13.7
 18182         1.07        22.7
 18183         2.21        17.3
 18184         2.08        15.7
 18185          .73        15.2
 18186     16491.00         1.3
 18187     22300.91         1.3
 18188     11915.00         1.3
 18191     21031.31         1.3
 18192     22031.21         1.3
 18193      2021.79         4.3
 18194     23200.91         1.2
 18195     26407.03         1.3
 18196     22130.09         1.3
 18197     17764.01         1.4
 18198     22243.97         1.3
 18200     14373.01         1.6
 18201     24200.39         1.2
 18202     23343.00         1.3
 18204     14593.75         1.6
 18205      2970.72         3.3
 18206     14393.75         1.6
 18207     24374.73         1.2
 18210        22.70         7.7
```

```
                                                                  PAGE  1
CONCORD SCIENTIFIC   NJTP   06-03-85

 RADON           STD.
 EXP. RATE       DEV.    SERIAL
(PCI/LITER)      PCT.    NUMBER  FIELD NOTES AND DATA
----------       ----    ------  ----------------------------------

      .32        25.3    13179
      .33        25.3    13172
      .34        22.7    13175
      .36        21.6    13180
      .40        21.1    13171
      .41        20.6    13178
      .49        19.1    13177
      .50        17.0    13173
      .75        15.2    13185
      .94        13.6    13181
     1.37        22.7    13182
     2.21        17.6    13183
     2.27        17.1    13174
     2.55        13.7    13184
     3.39         9.0    13176
    22.70         7.7    13216
  2021.79         4.0    13193
  2975.72         3.5    13205
 10491.03         1.6    13186
 11915.00         1.6    13190
 14376.51         1.5    13200
 14593.76         1.5    13236
 14595.76         1.5    13234
 17724.51         1.4    13197
 21621.51         1.3    13191
 22031.21         1.3    13192
 22130.09         1.3    13189
 22360.91         1.3    13187
 22457.03         1.3    13195
 22545.97         1.3    13196
 23200.91         1.2    13194
 23345.00         1.3    13202
 24200.39         1.2    13231
 24574.73         1.2    13237
```

CHAPTER 14

Radiation Protection Bureau
Health and Welfare Canada
Radiation Exposure Reports

Health and Welfare Canada Santé et Bien-être social Canada
Radiation Protection Bureau Bureau de la radioprotection

OCCUPATIONAL RADIATION HAZARDS DIVISION
DIVISION DES DANGERS DE L'EXPOSITION PROFESSIONNELLE
OTTAWA, ONTARIO K1A-1C1
Technical: 613-996-4797. Technique
Administration: 613-996-3777: Administration

RADIATION EXPOSURE REPORT — RAPPORT D'EXPOSITION AUX RADIATIONS

GROUP CODE CODE DU GROUPE	DATE OF REPORT DATE DU RAPPORT	PAGE
53 (F)16316	03/22/85	1

CONCORD SCIENTIFIC CORPORATION
ATTN JIM OGILVIE
SENIOR OCCUPATIONAL HYGIENIST
2 TIPPETT ROAD
DOWNSVIEW ONTARIO
M3H 2V2

TLD SERVICE SERVICE DTL
QUARTERLY TRIMESTRIEL
RADIATION: X-GAMMA-BETA

Monitor number Numéro du moniteur		Name — Nom		DOSE ESTIMATE (mSv) DOSE ESTIMÉE First line — Body Second line — Skin Première ligne — Corps Deuxième ligne — Peau					Signals Signaux	Anomalies
					Current — Courante					
Period Période	Serial Série				Period Période	Quarter Trimestre	This year Cette année	To date À ce jour	¼ ²⁄₄ ¾ ⁴⁄₄ Y	
284	002487	VISITOR			- -					6
2284	018221	VISITOR			- -					6
284	022437	VISITOR			- -					6
2284	022518	VISITOR			- -					6
284	046065	VISITOR			- -					6
284	074561	VISITOR			- -					6
2284	076097	VISITOR			- -					6
284	076200	VISITOR			- -					6
2284	080059	VISITOR			- -					6
284	092696	VISITOR			- -					6
284	103678	VISITOR			- -					6
2284	105807	VISITOR			- -					6
284	136961	VISITOR			- -					6
2284	141766	VISITOR			- -					6
284	146360	VISITOR			- -					6
2284	039933	NOT USED								6
284	072260	NOT USED								6
2284	075003	NOT USED								6
2284	083240	NOT USED								6
284	089456	NOT USED								6
284	125446	NOT USED								6
2284	133306	NOT USED								6
284	157684	NOT USED								6
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

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REGARDEZ LE VERSO POUR L'EXPLICATION DES COLONNES

Health and Welfare Canada Santé et Bien-être social Canada
Radiation Protection Bureau Bureau de la radioprotection

OCCUPATIONAL RADIATION HAZARDS DIVISION
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OTTAWA, ONTARIO K1A-1C1
Technical: 613-996-4797: Technique
Administration: 613-996-3777: Administration

RADIATION EXPOSURE REPORT — RAPPORT D'EXPOSITION AUX RADIATIONS

GROUP CODE CODE DU GROUPE	DATE OF REPORT DATE DU RAPPORT	PAGE
53(F)16316	06/18/85	1

CONCORD SCIENTIFIC CORPORATION
ATTN JIM OGILVIE
SENIOR OCCUPATIONAL HYGIENIST
2 TIPPETT ROAD
DOWNSVIEW ONTARIO
M3H 2V2

TLD SERVICE SERVICE DTL
QUARTERLY TRIMESTRIEL
RADIATION: X-GAMMA-BETA

Monitor number Numéro du moniteur		Name — Nom		DOSE ESTIMATE (mSv) DOSE ESTIMÉE First line — Body Second line — Skin Première ligne — Corps Deuxième ligne — Peau					Signals Signaux	Anomalies
					Current — Courante					
Period Période	Serial Série				Period Période	Quarter Trimestre	This year Cette année	To date À ce jour	¼ ²⁄₄ ¾ ⁴⁄₄ Y	
2284	160313	VISITOR.			- -	/				6
0485	003421	VISITOR.			- -	/				6
0485	018767	VISITOR.			- -	/				6
0485	040229	VISITOR.			.2 .3					6
0485	042855	VISITOR.			.3 .3					6
0485	046873	VISITOR.			- -	/				6
0485	063202	VISITOR.			- -	/				6
0485	083792	VISITOR.			- -	/				6
0485	096103	VISITOR.			.3 .3					6
0485	099571	VISITOR,			.4 .4					6
0485	102295	VISITOR			- -	/				6
0485	102726	VISITOR			- -	/				6
0485	111662	VISITOR			- -	/				6
0485	115915	VISITOR-			.2 .2					56C
0485	117732	VISITOR-			- -	/				6
0485	145895	VISITOR			- -	/				6
0485	010125	NOT USED								6
0485	033407	NOT USED								6
0485	069467	NOT USED								6
0485	088083	NOT USED								6
0485	094760	NOT USED								6
0485	099093	NOT USED								6
0485	108886	NOT USED								6
0485	139327	NOT USED								6
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

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Health and Welfare Canada Santé et Bien-être social Canada
Radiation Protection Bureau Bureau de la radioprotection

OCCUPATIONAL RADIATION HAZARDS DIVISION
DIVISION DES DANGERS DE L'EXPOSITION PROFESSIONNELLE
OTTAWA, ONTARIO K1A-1C1
Technical: 613-996-4797 Technique
Administration: 613-996-3777 Administration

RADIATION EXPOSURE REPORT — RAPPORT D'EXPOSITION AUX RADIATIONS

GROUP CODE CODE DU GROUPE	DATE OF REPORT DATE DU RAPPORT	PAGE
53(F)16316	09/11/85	1

CONCORD SCIENTIFIC CORPORATION
ATTN JIM OGILVIE
SENIOR OCCUPATIONAL HYGIENIST
2 TIPPETT ROAD
DOWNSVIEW ONTARIO
M3H 2V2

TLD SERVICE SERVICE DTL
QUARTERLY TRIMESTRIEL
RADIATION: X-GAMMA-BETA

Monitor number / Numéro du moniteur: Period Période	Monitor number / Numéro du moniteur: Serial Série	Name — Nom			DOSE ESTIMATE (mSv) DOSE ESTIMÉE (First line — Body, Second line — Skin / Première ligne — Corps, Deuxième ligne — Peau): Current — Courante: Period Période	Current — Courante: Quarter Trimestre	This year Cette année	To date À ce jour	Signals Signaux ¼ ½ ¾ ⁴⁄₄ Y	Anomalies
1085	024871	[illegible]ELL GA			- -	- -	- -	.2 .2		
1085	048319	[illegible] I G D			- -	- -	- -	- -		
1085	048804	[illegible]CK-[illegible]TH C			.3 .3	.3 .3	.3 .3	.3 .3		
1085	150065	L[illegible]S[illegible] OL			.2 .2	.2 .2	.2 .2	.2 .2		
1085	061801	MATTHEWS [illegible]			- -	- -	- -	- -		
1085	073319	[illegible]EAYS RO			.2 .2	.2 .2	.2 .2	.2 .2		
1085	109107	OTOOLE L			- -	- -	- -	- -		
1085	131694	SPONTON S			- -	- -	- -	- -		
1085	065060	VISITOR			.3 .3					
1085	112932	VISITOR			.2 .2					
1085	102466	VISITOR			1.2 2.2					
1085	013343	NOT USED								
1085	020473	NOT USED								
1085	021322	NOT USED								
1085	036673	NOT USED								
1085	059767	NOT USED								
1085	087244	NOT USED								
1085	091916	NOT USED								
1085	119031	NOT USED								5C
1085	140394	NOT USED								
1085	146215	NOT USED								
1085	150632	NOT USED								
1085	155632	NOT USED								
		*** DECLARED LOST — DECLARE(S) PERDU(S) ***								
1085	116562	CATON RC								
1085	012701	MORAN MD								
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

Concord Scientific Corporation

SEE REVERSE FOR EXPLANATION OF COLUMN NUMBERS
REGARDEZ LE VERSO POUR L'EXPLICATION DES COLONNES

Health and Welfare Canada Santé et Bien-être social Canada
Radiation Protection Bureau Bureau de la radioprotection

OCCUPATIONAL RADIATION HAZARDS DIVISION
DIVISION DES DANGERS DE L'EXPOSITION PROFESSIONNELLE
OTTAWA, ONTARIO K1A-1C1
Technical: 613-998-4797, Technique
Administration: 613-998-3777: Administration

RADIATION EXPOSURE REPORT — RAPPORT D'EXPOSITION AUX RADIATIONS

GROUP CODE CODE DU GROUPE	DATE OF REPORT DATE DU RAPPORT		PAGE
53 (F) 16316	11/25/85	521	1

CONCORD SCIENTIFIC CORPORATION
ATTN JIM OGILVIE
SENIOR OCCUPATIONAL HYGIENIST
2 TIPPETT ROAD
DOWNSVIEW ONTARIO
M3H 2V2

TLD SERVICE SERVICE DTL
QUARTERLY TRIMESTRIEL
RADIATION: X-GAMMA-BETA

Monitor number Numéro du moniteur		Name — Nom			DOSE ESTIMATE (mSv) DOSE ESTIMÉE First line — Body Second line — Skin Premiere ligne — Corps Deuxième ligne — Peau				Signals Signaux	Anomalies
Period Période	Serial Série				Current — Courante Period Période	Quarter Trimestre	This year Cette année	To date À ce jour	¼ ²⁄₄ ¾ ⁴⁄₄ Y	
1685	108868	DOWNING D			- -	- -	- -	- -		
1685	154308	DUCKWORTH C			- -	- -	.3 .3	.3 .3		
1685	103122	LUSH DL			- -	- -	.2 .2	.2 .2		
1685	110474	MEAYS BD			- -	- -	.2 .2	.2 .2		
1685	104969	OTOOLE L			- -	- -	- -	- -		
1685	106096	SNODGRASS W			- -	- -	- -	- -		
1685	002289	VISITOR			- -					
1685	018600	VISITOR			- -					
1685	055752	VISITOR			- -					
1685	099741	VISITOR			- -					
1685	115654	VISITOR			- -					
1685	138055	VISITOR			- -					
1685	009456	NOT USED								
1685	027449	NOT USED								
1685	042844	NOT USED								
1685	078226	NOT USED								
1685	078299	NOT USED								
1685	087802	NOT USED								
1685	096096	NOT USED								
1685	116227	NOT USED								
1685	129968	NOT USED								
1685	135697	NOT USED								
1685	157701	NOT USED								
1685	162437	NOT USED								
1685	163576	NOT USED								
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

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CORPORATION

SEE REVERSE FOR EXPLANATION OF COLUMN NUMBERS
REGARDEZ LE VERSO POUR L'EXPLICATION DES COLONNES

NUMBER **EXPLANATION (by column number)**

(1) An identification number of ten digits; the first two digits refer to the period number, the second two to the year and the last six to the monitor serial number.

(2) Full name and initials (surname abbreviated by an asterisk if more than eleven characters).

(3) Asterisk indicates person currently active at more than one group. Cumulative totals are all inclusive.

(4) Unless indicated in this column, the first record line indicates the body dose estimate while the second gives the skin dose estimate. Other dose estimates are titled by HD/TT (head dose), EXT 2 (left hand and arm), EXT 3 (right hand and arm), EXT 4 (left foot and leg), EXT 5 (right foot and leg) and RDWLM (radon daughter working level months) in this column.

(5) Current period estimated dose (mSv).

(6) Cumulative dose for current quarter (mSv).

(7) Cumulative dose for current year (mSv).

N.B.
0.1 mSv = 10 mRem
"—" means less than 0.2 mSv

(8) Cumulative dose to date from RPB records (mSv). An asterisk indicates other records included and/or available.

(9)

SIGNALS	BODY	SKIN
Quarter	30 mSv	150 mSv
Year	50 mSv	300 mSv
	HEAD	EXTREMITIES
Quarter	80 mSv	380 mSv
Year	150 mSv	750 mSv

(10) Unusual occurrence indicated.

1. Monitor Contaminated
2. Control Monitor Exposed
3. Faulty Holder
4. Foil Image Absent
5. Monitor Damaged
6. Late Receiving and / or Reporting
7. Non-Personal
8. Thermal Neutron Exposure Included
9. Non-Uniform

A. Chip Missing.
B. Ultra Violet (U.V.) Exposure possible
C. Questionable Exposure

NUMÉRO DE COLONNE **EXPLICATION (par le numéro des colonnes)**

(1) Un numéro d'identification de dix chiffres dont les deux premiers indiquent la période, les deux suivants, l'année et les six derniers, le numéro de série du moniteur.

(2) Nom au complet et initiales (les surnoms sont abrégés par un astérisque s'il y a plus de onze lettres).

(3) L'astérisque indique que la personne est présentement active dans plus d'un groupe. Les totaux sont cumulatifs

(4) À moins d'indication contraire dans cette colonne, la première ligne des données indique la dose corporelle estimée et la seconde, la dose à la peau estimée. Les autres doses estimées seront indiquées dans cette colonne comme suit: HD/TT (dose à la tête), EXT 2 (main et bras gauches), EXT 3 (main et bras droits), EXT 4 (pied et jambe gauches), EXT 5 (pied et jambe droits) et RDWLM (produit de filiation du radon, niveau opérationel / mois).

(5) Dose estimée à la période courante (mSv).

(6) Dose cumulative du trimestre courant (mSv).

(7) Dose cumulative de l'année courante (mSv).

N.B.
0.1 mSv = 10 mRem
"—" indique moins que 0.2 mSv

(8) Dose cumulative, à ce jour, obtenues des dossiers du B.R. (mSv). Un astérisque indique les autres données incluses ou disponibles.

(9)

SIGNAUX	CORPS	PEAU
trimestre	30 mSv	150 mSv
année	50 mSv	300 mSv
	TÊTE	EXTRÉMITÉS
trimestre	80 mSv	380 mSv
année	150 mSv	750 mSv

(10) Anomalies indiquées.

1. Moniteur contaminé
2. Moniteur de contrôle exposé
3. Porte-moniteur défectueux
4. Image-filtre absente
5. Moniteur endommagé
6. Réception et / ou résultat en retard
7. Non personnel
8. Exposition à des neutrons thermiques incluse
9. Moniteur sans uniformité

A. DTL égaré
B. Exposition aux rayonnements Ultra-Violet (U.V.) possible
C. Exposition contestable

Concord Scientific Corporation

CHAPTER 15

Atmospheric Component Station Chronology

MONITORING STATION SUMMARY

STATION ID: A1 STATION TYPE: Ambient Radon STATION LOCATION:

STATION DESCRIPTION: Located outside of meadow about 15 m south of road to old townsite on a birch tree. Site is southwest of Gunnar Main tailings area.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
29/11/84	PF, MDM	Prepared site, installed protective canister.	Site snow covered.	0.01-0.02
9/12/84	PF	Installed cup.		
1/05/85	PF, THM	Collected and replaced cup.	80+% snow covered near site.	0.01-0.02
23/06/85	THM	Collected and replaced cup.		0.03-0.04
28/07/85	THM	Collected cup, dismantled site.		0.02-0.03

MONITORING STATION SUMMARY

STATION ID: A2

STATION TYPE: Ambient Radon

STATION LOCATION:

STATION DESCRIPTION: Located on west side of road leading to large building adjacent to southwest end of Gunnar Main tailings.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
29/11/84	PF, MDM	Prepared site, installed protective canister.	Site snow covered. Used tree stump to support monitor.	0.01-0.02
9/12/84	PF	Installed cup.		
1/05/85	PF, THM	Collected and replaced cup.	80+% snow covered near site.	0.03-0.04
23/06/85	THM	Collected and replaced cup.		0.03-0.05
28/07/85	THM	Collected cup, dismantled site.		0.02-0.03

MONITORING STATION SUMMARY

STATION ID: A3 STATION TYPE: Ambient Radon STATION LOCATION:

STATION DESCRIPTION: Located in woods between fork of two roads to west of lakefront playing field. Site is south of Gunnar Main tailings close to St. Mary's Channel.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
30/11/84	PF, MDM	Prepared site, installed protective canister and cup.	Site snow covered. Support tree appeared to be a beech.	
1/05/85	PF, THM	Collected and replaced cup.	Site snow covered.	0.01-0.02
23/06/85	THM	Collected and replaced cup.		0.02-0.04
28/07/85	THM	Collected cup, dismantled site.		0.02-0.04

MONITORING STATION SUMMARY

STATION ID: A4 STATION TYPE: Ambient Radon STATION LOCATION:

STATION DESCRIPTION: Located in woods about 25 m southeast of Gunnar Main tailings and 10 m southwest of main sluice. Co-located with ambient site A14.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
30/11/84	PF, MDM	Prepared site, installed protective canister and cup.	Site snow covered. Tree used to support monitor appeared to be a beech.	0.02-0.04
30/04/85	PF, THM	Collected and replaced cup.	50% snow covered - snow coloured red-brown by particles of sand/dust.	0.03-0.05
23/06/85	THM	Collected and replaced cup.		0.05-0.08
28/07/85	THM	Collected cup, dismantled site.		0.04-0.06

MONITORING STATION SUMMARY

STATION ID: A5 STATION TYPE: Ambient Radon STATION LOCATION:

STATION DESCRIPTION: Located beside old road with the remains of a cabin on the other side east of the waste rock pile. Access is from airport road.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
3/12/84	PF, MDM	Prepared site, installed protective canister and cup.	Site snow covered. Used a conifer for supporting monitor.	0.01-0.02
1/05/85	PF, THM	Collected and replaced cup.	90% snow covered.	0.02-0.05
22/06/85	THM	Collected and replaced cup.		0.01-0.02
29/07/85	THM	Collected cup, dismantled site.		0.01-0.02

MONITORING STATION SUMMARY

STATION ID: A6　STATION TYPE: Ambient Radon　STATION LOCATION:

STATION DESCRIPTION: Located in a clearing about 400 m east of earthen berm on east side of Gunnar Main tailings on a 6 m tree stump.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
3/12/84	PF, MDM	Prepared site, installed protective canister and cup.	Site snow covered.	
30/04/85	PF, THM	Collected and replaced cup.	Site snow covered - situated alongside runoff channel - 30 cm snow on 90 cm water.	
21/06/85	THM	Collected and replaced cup.	Filter of cup had been shredded by an animal. Spider found in cup. Gamma reading of this site much higher than at other ambient sites.	0.63-0.67
28/07/85	THM		Filter had been shredded again. Drierite pouch was missing. Considerable amount of tailings material washed down to be deposited at site.	0.60-0.66

MONITORING STATION SUMMARY

STATION ID: A7 STATION TYPE: Ambient Radon STATION LOCATION:

STATION DESCRIPTION: Located in a highly wooded area about 50 m in from the northeast corner of Gunnar Main tailings.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
1/12/84	PF, MDM	Prepared site, installed protective canister and cup.	Site snow covered. Used solitary pine tree to support monitor.	0.03-0.05
30/04/85	PF, THM	Collected and replaced cup.	30% snow covered near site.	
21/06/85	THM	Collected and replaced cup.		0.03-0.05
28/07/85	THM	Collected cup, dismantled site.	Filter had been shredded.	0.02-0.04

MONITORING STATION SUMMARY

STATION ID: A8 STATION TYPE: Ambient Radon STATION LOCATION:

STATION DESCRIPTION: Located in a small clearing on a hill overlooking northwestern side of Gunnar Main tailings.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
1/12/84	PF, MDM	Prepared site, installed protective canister and cup.	Site snow covered. Used black spruce to support monitor.	0.01-0.02
30/04/85	PF, THM	Collected and replaced cup.	Site snow covered (20 cm) - snow covered 50 cm of water.	
21/06/85	THM	Collected and replaced cup.	Site located in sphagnum bag - very wet.	
28/07/85	THM	Collected cup, dismantled site.	Site very wet.	0.01-0.02

MONITORING STATION SUMMARY

STATION ID: A9 STATION TYPE: Ambient Radon STATION LOCATION:

STATION DESCRIPTION: Located on top of a small knoll at a site north of Gunnar Main, southwest of Gunnar Central and south of Langley Bay tailings areas. Co-located with ambient site A15.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
1/12/84	PF, MDM	Prepared site, installed protective canister and cup.	Site snow covered. Requires quite a hike to reach it from the frog pond.	0.01-0.02
1/05/85	SS, PF, THM	Collected and replaced cup.	Shawn was guided to site by helicopter.	
21/06/85	THM		Filter on cup had been shredded, likely by a bear. Spider found in cup.	
28/07/85	THM	Collected cup, dismantled site.	Site very wet.	0.01-0.03

MONITORING STATION SUMMARY

STATION ID: A10   STATION TYPE: Ambient Radon   STATION LOCATION:

STATION DESCRIPTION: Located near top of the ridge overlooking the south side of Gunnar Central tailings.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
4/12/84	PF, SS	Prepared site, installed protective canister and cup.	Site snow covered. Located about 30 m higher than surface of Gunnar Central.	0.01-0.02
1/05/85	PF, THM	Collected and replaced cup.		0.01-0.02
22/06/85	THM	Collected and replaced cup.		0.01-0.02
27/07/85	THM	Collected cup, dismantled site.	Filter had been shredded.	0.01-0.02

MONITORING STATION SUMMARY

STATION ID: A11　　STATION TYPE: Ambient Radon　　STATION LOCATION:

STATION DESCRIPTION: Nominal background site. Located just west of sharp bend in airport road, several kilometres east of Gunnar Main and Gunnar Central tailings areas.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
3/12/84	PF, MDM	Prepared site, installed protective canister and cup.	Site snow covered. Used tall black spruce to support monitor.	0.00-0.01
1/05/85	PF, THM	Collected and replaced cup.		0.00-0.01
22/06/85	THM	Collected and replaced cup.		0.00-0.01
29/07/85	THM	Collected cup, dismantled site.	Filter had been shredded by animals.	0.00-0.01

MONITORING STATION SUMMARY

STATION ID: A12

STATION TYPE: Ambient Radon

STATION LOCATION:

STATION DESCRIPTION: Located on a ridge to east of Gunnar Central tailings area in a large clearing.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
4/12/84	PF, SS	Prepared site, installed protective canister and cup.	Site snow covered. Used a 4 m black spruce to support monitor. Site about 20 m higher than Gunnar Central tailings.	0.02-0.03
1/05/85	PF, THM	Collected and replaced cup.		0.02-0.03
22/06/85	THM	Collected and replaced cup.		0.02-0.03
27/07/85	THM	Collected cup, dismantled site.	Filter had been shredded by animals.	0.01-0.03

MONITORING STATION SUMMARY

STATION ID: A13 STATION TYPE: Ambient Radon STATION LOCATION:

STATION DESCRIPTION: Located in a clearing between Gunnar Central and Langley Bay just north and and east of main channel connecting the two tailings areas.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
4/12/84	PF, SS	Prepared site, installed protective canister and cup.	Site snow covered. Used a birch tree to support monitor.	0.03-0.04
1/05/85	PF, THM	Collected and replaced cup.		0.01-0.02
22/06/85	THM	Collected and replaced cup.	Filter of cup was in pieces and cup was cracked. Bear feces were found nearby. Spider found in cup.	0.03-0.04
27/07/85	THM	Collected cup, dismantled site.		0.03-0.06

MONITORING STATION SUMMARY

STATION ID: A14 STATION TYPE: Ambient Radon STATION LOCATION:

STATION DESCRIPTION: Located in woods about 25 m southeast of Gunnar Main tailings and 10 m southwest of main sluice. Co-located with ambient site A14.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
30/11/84	PF, MDM	Prepared site, installed protective canister and cup.	Site snow covered. Tree used to support monitor, appeared to be a beech.	0.02-0.04
30/04/85	PF, THM	Collected and replaced cup.	As for A4.	0.03-0.05
23/06/85	THM	Collected and replaced cup.		0.05-0.08
28/07/85	THM	Collected cup, dismantled site.		0.04-0.06

MONITORING STATION SUMMARY

STATION ID: A15 STATION TYPE: Ambient Radon STATION LOCATION:

STATION DESCRIPTION: Located on top of a small knoll at a site north of Gunnar Main, southwest of Gunnar Central, and south of Langley Bay tailings areas. Co-located with ambient site A9.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
1/12/84	PF, MDM	Prepared site, installed protective canister and cup.	Site snow covered. Required quite a hike to reach it from the frog pond.	0.01-0.02
1/05/85	PF, THM	Collected and replaced cup.		
21/06/85	THM	Collected and replaced cup.		
28/07/85	THM	Collected cup, dismantled site.		0.01-0.03

MONITORING STATION SUMMARY

STATION ID: BG1 STATION TYPE: Background Gamma STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A1.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
1/05/85	PF, THM	Installed dosimeter.		
23/06/85	THM	Collected and replaced dosimeter.		0.03-0.04
28/07/85	THM	Collected dosimeter, dismantled site.		0.02-0.03

MONITORING STATION SUMMARY

STATION ID: BG2 STATION TYPE: Background Gamma STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A2.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
1/05/85	PF, THM	Installed dosimeter.		0.03-0.04
23/06/85	THM	Collected and replaced dosimeter.		0.03-0.05
28/07/85	THM	Collected dosimeter, dismantled site.		0.02-0.03

MONITORING STATION SUMMARY

STATION ID: BG3　STATION TYPE: Background Gamma　STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A3.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
1/05/85	PF, THM	Installed dosimeter.		0.01-0.02
23/06/85	THM	Collected and replaced dosimeter.		0.02-0.04
28/07/85	THM	Collected dosimeter, dismantled site.		0.02-0.04

MONITORING STATION SUMMARY

STATION ID: BG4 STATION TYPE: Background Gamma STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A4/A14. Co-located with BG14.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
30/04/85	PF, THM	Installed dosimeter.		0.03-0.05
23/06/85	THM	Collected and replaced dosimeter.		0.05-0.08
28/07/85	THM	Collected dosimeter, dismantled site.		0.04-0.06

MONITORING STATION SUMMARY

STATION ID: BG5 STATION TYPE: Background Gamma STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A5.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
1/05/85	PF, THM	Installed dosimeter.		0.02-0.03
23/06/85	THM	Collected and replaced dosimeter.		0.01-0.02
28/07/85	THM	Collected dosimeter, dismantled site.		0.01-0.02

MONITORING STATION SUMMARY

STATION ID: BG6 STATION TYPE: Background Gamma STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A6.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
30/04/85	PF, THM	Installed dosimeter.		
21/06/85	THM	Collected and replaced dosimeter.	Horizontal pole supporting dosimeter had been torn from tree and both lay on ground at base of tree. Dosimeter had teethmarks in its protective housing and had been pulled off pole. Highest spot gamma reading of all ambient sites.	0.63-0.67
28/07/85	THM	Collected dosimeter, dismantled site.		0.01-0.02

MONITORING STATION SUMMARY

STATION ID: BG7 STATION TYPE: Background Gamma STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A7.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
30/04/85	PF, THM	Installed dosimeter.		
21/06/85	THM	Collected and replaced dosimeter.		0.03-0.05
28/07/85	THM	Collected dosimeter, dismantled site.	Horizontal pole and dosimeter had been torn from host tree and both were found on ground.	0.02-0.04

MONITORING STATION SUMMARY

STATION ID: BG8
STATION TYPE: Background Gamma
STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A8.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
30/04/85	PF, THM	Installed dosimeter.		
21/06/85	THM	Collected and replaced dosimeter.		
28/07/85	THM	Collected dosimeter, dismantled site.		0.01-0.02

MONITORING STATION SUMMARY

STATION ID: BG9
STATION TYPE: Background Gamma
STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A9/A15.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
1/05/85	SS	Installed dosimeter.	Taken to site by helicopter.	
21/06/85	THM	Collected and replaced dosimeter.	Pole supporting dosimeter had been torn from tree and both pole and dosimeter were found on the ground.	
28/07/85	THM	Collected dosimeter, dismantled site.		0.01-0.03

MONITORING STATION SUMMARY

STATION ID: BG10
STATION TYPE: Background Gamma
STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A10.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
1/05/85	PF, THM	Installed dosimeter.		0.01-0.02
21/06/85	THM	Collected and replaced dosimeter.		0.01-0.02
28/07/85	THM	Collected dosimeter, dismantled site.	End of pole to which dosimeter was attached had been pulled closer to ground.	0.01-0.02

MONITORING STATION SUMMARY

STATION ID: BG11　　STATION TYPE: Background Gamma　　STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A11.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
1/05/85	PF, THM	Installed dosimeter.		0.01-0.01
21/06/85	THM	Collected and replaced dosimeter.		0.01-0.01
28/07/85	THM	Collected dosimeter, dismantled site.	End of pole to which dosimeter was attached had been pulled closer to ground. Dosimeter's weatherproofing housing had teethmarks in it.	0.01-0.01

MONITORING STATION SUMMARY

STATION ID: BG12 STATION TYPE: Background Gamma STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A12.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
1/05/85	PF, THM	Installed dosimeter.		0.02-0.03
21/06/85	THM	Collected and replaced dosimeter.		0.02-0.03
28/07/85	THM	Collected dosimeter, dismantled site.	End of pole to which dosimeter was attached had been pulled closer to ground. Dosimeter's weatherproofing housing had teethmarks in it and was partially filled with water so that dosimeters was submersed.	0.01-0.03

MONITORING STATION SUMMARY

STATION ID: BG13 STATION TYPE: Background Gamma STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A13.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
1/05/85	PF, THM	Installed dosimeter.		0.01-0.02
21/06/85	THM	Collected and replaced dosimeter.	Pole and attach dosimeter had been torn from tree and were found on the ground.	0.03-0.04
28/07/85	THM	Collected dosimeter, dismantled site.	End of pole to which dosimeter was attached had been pulled closer to ground.	0.03-0.06

MONITORING STATION SUMMARY

STATION ID: BG14 STATION TYPE: Background Gamma STATION LOCATION:

STATION DESCRIPTION: Located at ambient site A4/A14. Co-located with BG4.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
30/04/85	PF, THM	Installed dosimeter.		0.03-0.05
23/06/85	THM	Collected and replaced dosimeter.		0.05-0.08
28/07/85	THM	Collected dosimeter, dismantled site.		0.04-0.06

MONITORING STATION SUMMARY

STATION ID: C3 STATION TYPE: Radon Flux (can) STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at south end of Gunnar Main tailings between two sluices. Co-located with M3 mat site, close to piezometer nest 1.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
9/12/84	Drillers PF, MDM	Installed 3 pipes at site. Deployed cup in tall pipe.		
10/12/84	MDM, SS	Deployed cup in other 2 pipes.	Some snow at bottom of 2 shorter pipes, tall pipe snow-free. Difficult to seal pipe exteriors with tape in cold. (as for M3)	
30/04/85	PF, THM	Collected and replaced 3 cups.		
23/06/85	THM	Collected and replaced 3 cups.		
26/07/85	THM	Collected and replaced 3 cups.	Deployed 3 short-term detectors.	
30/07/85	THM	Collected 3 cups, capped pipes.	Retrieved 3 short-term detectors.	

MONITORING STATION SUMMARY

STATION ID: C8   STATION TYPE: Radon Flux (can)   STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at north end of Gunnar Main tailings close to exit to frog pond. Surface stream lies just to west. Co-locted with M8 mat site, close to piezometer nest 3.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
6/12/84	Drillers	Installed 3 pipes at site.		
11/12/84	MDM, SS	Deployed cup in 3 pipes.	Difficult to seal pipe exteriors with tape in cold. (as for M8)	
30/04/85	PF, THM	Collected and replaced 3 cups.		
21/06/85	THM	Collected and replaced 3 cups.		
26/07/85	THM	Collected and replaced 3 cups.	Deployed 3 short-term detectors.	
30/07/85	THM	Collected 3 cups, capped pipes.	Retrieved 3 short-term detectors.	

MONITORING STATION SUMMARY

STATION ID: M1
STATION TYPE: Radon Flux (mat)
STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at south end of Gunnar Main tailings just to south of second sluice in an elevated section. Grassy patch to south.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
2/12/84	PF, DD	Prepared site, installed mat and cup.	Site snow covered.	0.24-0.28
30/04/85	PF, THM	Collected and replaced cup.	Site clear of snow.	0.32-0.35
23/06/85	THM	Collected and replaced cup. Installed thermal insulation.		0.38-0.42
29/07/85	THM	Collected cup, dismantled site.	All three layers of plastic had been punctured, apparently by birds. (for 'birds' read 'monster-ravens)	0.34-0.38

MONITORING STATION SUMMARY

STATION ID: M2 STATION TYPE: Radon Flux (mat) STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located near southwest corner of Gunnar Main tailings to south of low marshy area on a grassy knoll.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
2/12/84	PF, MDM	Prepared site, installed mat and cup.	Site snow covered.	0.20-0.26
30/04/85	PF, THM	Collected and replaced cup.	Site was wet but no water was found in cup. Site clear of snow.	0.28-0.32
21/06/85	THM	Collected and replaced cup with 2 cups. Installed thermal insulation.	Deployed 2 short-term detectors.	0.30-0.33
25/06/85	THM	Collected and replaced cups with one cup.	Retrieved 2 short-term detectors.	
28/07/85	THM	Collected cup, dismantled site.		0.28-0.34

MONITORING STATION SUMMARY

STATION ID: M3 STATION TYPE: Radon Flux (mat) STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at south end of Gunnar Main tailings between two sluices. Ground surface slightly crusty and uneven. Co-located with C3 can site, close to piezometer nest 1.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
11/12/84	MDM, SS	Prepared site, installed mat and cup.	Put in two Terradex cups.	
30/04/85	PF, THM	Collected and replaced cup.	Two cups collected, two new cups deployed. Site clear of snow.	0.24-0.26
23/06/85	THM	Collected and replaced cups. Installed thermal insulation.	Two cups again deployed.	0.28-0.32
26/06/85	THM	Collected one cup, deployed one cup.	Deployed one short-term detector. Only retrieved one of June/July cups.	0.29-0.32
30/07/85	THM	Collected two cups, dismantled site.	Retrieved short-term detector and remaining June/July cup.	

MONITORING STATION SUMMARY

STATION ID: M4

STATION TYPE: Radon Flux (mat)

STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located to southwest of centre of Gunnar Main tailings. Marshy area lies to west. Close to piezometer nest 2.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
30/04/85	PF, THM	Prepared site, installed mat and cup.	Site not installed until spring campaign. Site clear of snow.	0.28-0.30
21/06/85	THM	Collected and replaced cup with two cups. Installed thermal insulation.	Deployed 2 short-term detectors.	0.32-0.37
25/06/85	THM	Collected and replaced cups with one cup.	Retrieved 2 short-term detectors.	
29/07/85	THM	Collected cup, dismantled site.	Heavy drifting of sand onto mat for June and July collecting periods.	0.38-0.42

MONITORING STATION SUMMARY

STATION ID: M5
STATION TYPE: Radon Flux (mat)
STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located on Gunnar Main tailings area to north-northeast of main sluice. Ground surface very smooth and sandy, slopes slightly to southeast.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
6/12/84	PF, MDM, SS	Prepared site, installed cup and mat.	Nearly ideal mat site.	
30/04/85	PF, THM	Collected and replaced cup.	Site clear of snow.	0.29-0.31
21/06/85	THM	Collected and replaced cup. Installed thermal insulation.	Deployed short-term detector.	0.28-0.32
25/06/85	THM	Collected and replaced cup.	Retrieved short-term detector.	
26/07/85	THM	Collected and replaced cup.	Deployed short-term detector.	0.33-0.37
30/07/85	THM	Collected cup, dismantled site.	Retrieved short-term detector. Heavy drifting of sand onto mat for the collecting period.	

MONITORING STATION SUMMARY

STATION ID: M6 STATION TYPE: Radon Flux (mat) STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located near middle of Gunnar Main tailings just to north of meteorological tower. Grond surface dry with a hard fractured crust.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
2/12/84	PF, MDM	Prepared site, installed cup and mat.	Site snow covered.	
30/04/85	PF, THM	Collected and replaced cup.	Site clear of snow.	0.42-0.46
23/06/85	THM	Collected and replaced cup. Installed thermal insulation.		0.45-0.50
29/07/85	THM	Collected cup, dismantled site.		0.40-0.46

MONITORING STATION SUMMARY

STATION ID: M7　　STATION TYPE: Radon Flux (mat)　　STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located on west side of Gunnar Main tailings area on a grassy knoll. Marshy area to east, grove of dead trees to west.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
2/12/84	PF, MDM, DD	Prepared site, installed cup and mat.	First mat site installed.	0.30-0.35
30/04/85	PF, THM	Collected and replaced cup.	Site was wet but no water was found in cup. Site clear of snow.	0.37-0.42
21/06/85	THM	Collected and replaced cup with two cups. Installed thermal insulation.	Deployed 2 short-term detectors.	0.43-0.47
25/06/85	THM	Collected and replaced cup.	Retrieved 2 short-term detectors.	
29/07/85	THM	Collected and replaced cup.	Top two layers of plastic hood had been shredded, third layer appeared to be intact. Deployed short-term detector.	0.45-0.48
30/07/85	THM	Collected cup, dismantled site.	Retrieved short-term detector.	

MONITORING STATION SUMMARY

STATION ID: M8 STATION TYPE: Radon Flux (mat) STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at north end of Gunnar Main tailings close to exit to frog pond. Ground surface grassy. Surface stream lies just to west. Co-located with C3 can site and piezometer nest 3.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
30/04/85	PF, THM	Prepared site, installed mat and cups.	Site not installed until spring campaign. Two cups deployed.	0.22-0.26
21/06/85	THM	Collected and replaced cups. Installed thermal insulation.	Two cups again deployed. Cups collected had a lime-like build-up of white crystals adhering to them at ground level.	0.39-0.44
25/06/85	THM	Collected cups, installed new cup.	Deployed short-term detector.	0.42-0.48
30/07/85	THM	Collected cup, dismantled site.	Retrieved short-term detector.	

MONITORING STATION SUMMARY

STATION ID: M9   STATION TYPE: Radon Flux (mat)   STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at southeast end of Gunnar Main tailings. Ground surface farily level with some grassy stubble.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
6/12/84	PF, MDM	Prepared site, installed cup and mat.	Used both sandbags and rocks as edging.	0.22-0.24
1/05/85	PF, THM	Collected and replaced cup.	Site clear of snow. Site quote wet - no water in cup. Cup frozen into plank in ground.	0.24-0.26
22/06/85	THM	Collected and replaced cup. Installed thermal insulation.		
27/07/85	THM	Collected cup, dismantled site.		0.30-0.34

MONITORING STATION SUMMARY

STATION ID: M10 STATION TYPE: Radon Flux (mat) STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located near centre of Gunnar Central tailings area. Ground surface fairly level, sandy, no vegetation.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
6/12/84	PF, SS	Prepared site, installed cup and mat.	Ice nearby (to west). Blue sand bags used.	0.18-0.22
1/05/85	PF, THM	Collected and replaced cup.	Site clear of snow.	0.20-0.22
22/06/85	THM	Collected and replaced cup. Installed thermal insulation.		0.20-0.23
27/07/85	THM	Collected cup, dismantled site.		0.24-0.28

MONITORING STATION SUMMARY

STATION ID: M11 STATION TYPE: Radon Flux (mat) STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located on east side of Gunnar Central tailings near trees on a small hummock. Ground surface rolling and uneven with considerable grass present.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
6/12/84	PF, MDM	Prepared site, installed cup and mat.	Ice within a metre of site on two sides. Ground very hard.	0.20-0.24
1/05/85	PF, THM	Collected and replaced cup.	Site clear of snow. Site very wet, cup in water but no water in cup.	0.24-0.28
22/06/85	THM	Collected and replaced cup. Installed thermal insulation.		0.32-0.35
27/07/85	THM	Collected cup, dismantled site.		0.29-0.32

MONITORING STATION SUMMARY

STATION ID: M12

STATION TYPE: Radon Flux (mat)

STATION LOCATION: Langley Bay

STATION DESCRIPTION: Located by south shore of Langley Bay on tailings between two outflow channels from Gunnar Central. Sandy, some grass.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
5/12/84	PF, SS	Prepared site, installed mat and cup.	Used sand and rocks as edging.	0.12-0.16
1/05/85	PF, THM	Collected and replaced cup.	Site sow free.	0.18-0.20
22/06/85	THM	Collected and replaced cup. Installed thermal insulation.		0.22-0.26
26/07/85	THM	Collected cup, dismantled site.		0.22-0.26

MONITORING STATION SUMMARY

STATION ID: M13 STATION TYPE: Radon Flux (mat) STATION LOCATION: Langley Bay

STATION DESCRIPTION: Located at northeast end of Langley Bay tailings on north side of main channel bisecting tailings. Surface fairly level and covered by grass.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
6/12/84	PF, SS	Prepared site, installed mat and cup.	Blue sand bags used.	0.28-0.32
1/05/85	PF, THM	Collected and replaced cup.	Area around mat still snow covered. 0.5 m snow on top of 0.1 m ice on top of mat. Site isolated by high water channel 1-1.5 m deep.	0.12-0.14
22/06/85	THM	Collected and replaced cup.		0.48-0.52
26/07/85	THM	Collected cup, dismantled site.		0.47-0.54

MONITORING STATION SUMMARY

STATION ID: MET1 STATION TYPE: Meteorological Tower STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
7/12/84	PF, MDM, SS	Dismantled instruments and tower at old site, transported to new site, raised and levelled tower.		
8/12/84	PF, MDM	Replaced instruments on tower.		
9/12/84	PF, MDM	Calibrated sensor, tested transmission.	Rain gauge did not register when tipped. Took back to SRC in Saskatoon.	
30/04/85	PF, THM	Inspected tower, replaced 2 m temperature probe, installed rain gauge, assembled and installed Stevenson screen beside tower.	Tower appeared to have weathered winter well.	
2/04/85	PF, THM	Installed, calibrated hygrothermograph.		
21/06/85	THM	Serviced tower, hygrothermograph.	Hygrothermograph paper had jammed, measurements were incomplete.	
22-25/06/85	THM	Checked hygrothermograph.	No problems.	

MONITORING STATION SUMMARY

STATION ID: MET1 (cont'd) STATION TYPE: Meteorological Tower STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
26/07/85	THM	Serviced tower, hygrothermograph.	Batteries for hygrothermograph were dead, 22 days of data had been collected.	
27-30/07/85	THM	Checked hygrothermograph.	No problems.	
?	?	Removed hygrothermograph.		

MONITORING STATION SUMMARY

STATION ID: TG1 STATION TYPE: Tailings Gamma STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at mat site M1.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
10/12/84	MDM, SS	Installed stake and 2 dosimeters.	Ground very hard, plugger drill used.	0.24-0.28
30/04/85	PF, THM	Collected and replaced 2 dosimeters.		0.32-0.35
23/06/85	THM	Site maintenance.		0.38-0.42
29/07/85	THM	Collected dosimeters, dismantled site.		0.34-0.38

MONITORING STATION SUMMARY

STATION ID: TG2 STATION TYPE: Tailings Gamma STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at mat site M2.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
10/12/84	MDM, SS	Installed stake and 2 dosimeters.	Ground very hard, pick axe used.	0.20-0.26
30/04/85	PF, THM	Collected and replaced 2 dosimeters.		0.28-0.32
21/06/85	THM	Site maintenance.		0.30-0.33
28/07/85	THM	Collected dosimeters, dismantled site.		0.28-0.34

MONITORING STATION SUMMARY

STATION ID: TG3 STATION TYPE: Tailings Gamma STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at mat site M3/can site C3.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
11/12/84	MDM	Installed stake and 4 dosimeters.	Ground very hard, plugger drill used.	
30/04/85	PF, THM	Collected 4 dosimeters, replaced with 2 new ones.		0.24-0.26
23/06/85	THM	Site maintenance.		0.28-0.32
26/07/85	THM	Collected 2 dosimeters, dismantled site.		0.29-0.33

MONITORING STATION SUMMARY

STATION ID: TG4 STATION TYPE: Tailings Gamma STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at mat site M4.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
30/04/85	PF, THM	Installed stake and 2 dosimeters.	Ground very hard, had to use pick axe.	0.28-0.30
21/06/85	THM	Site maintenance.		0.32-0.37
29/07/85	THM	Collected dosimeters, dismantled site.		0.38-0.42

MONITORING STATION SUMMARY

STATION ID: TG5 STATION TYPE: Tailings Gamma STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at mat site M5.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
10/12/84	MDM, SS	Installed stake and 2 dosimeters.	Ground very hard, pick axe used.	
11/12/84	MDM	Installed 2 additional dosimeters.		
30/04/85	PF, THM	Collected 4 dosimeters, replaced with 2 new ones.		0.29-0.31
21/06/85	THM	Site maintenance.		0.28-0.32
26/07/85	THM	Collected 1 m dosimeter, dismantled site.	Couldn't find ground level dosimeter.	0.33-0.37
30/07/85	THM	Retrieved ground level dosimeter.	Was partially buried in sand about 0.5 m from stake.	

MONITORING STATION SUMMARY

STATION ID: TG6 STATION TYPE: Tailings Gamma STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at mat site M6.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
10/12/84	MDM	Installed stake and 2 dosimeters.	Ground very hard, pick axe used.	
11/12/84	MDM	Installed 2 additional dosimeters.		
30/04/85	PF, THM	Collected 4 dosimeters, replaced with 2 new ones.		0.42-0.46
23/06/85	THM	Site maintenance.		0.45-0.50
29/07/85	THM	Collected 2 dosimeters, dismantled site.		0.40-0.46

MONITORING STATION SUMMARY

STATION ID: TG7 STATION TYPE: Tailings Gamma STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at mat site M7.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
10/12/84	MDM	Installed stake and 2 dosimeters.	Ground very hard, pick axe used.	0.30-0.35
30/04/85	PF, MDM	Collected and replaced 2 dosimeters.	Stake holding dosimeters had fallen over during winter - was set upright again.	0.37-0.42
21/06/85	THM	Site maintenance.		0.43-0.47
26/07/85	THM	Collected dosimeters, dismantled site.		0.45-0.48

MONITORING STATION SUMMARY

STATION ID: TG8 STATION TYPE: Tailings Gamma STATION LOCATION: Gunnar Main

STATION DESCRIPTION: Located at mat site M8/can site C3.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
11/12/84	MDM, SS	Installed stake and 4 dosimeters.	Ground very hard, pick axe used.	
30/04/85	PF, THM	Collected and replaced 2 dosimeters.		0.22-0.26
21/06/85	THM	Site maintenance.		0.39-0.44
26/07/85	THM	Collected dosimeters, dismantled site.		0.42-0.48

MONITORING STATION SUMMARY

STATION ID: TG9　　STATION TYPE: Tailings Gamma　　STATION LOCATION: Gunnar Central

STATION DESCRIPTION: Located at mat site M9.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
1/05/85	PF, THM	Installed stake and 2 dosimeters.	Ground very hard, had to use pick axe.	0.24-0.26
22/06/85	THM	Site maintenance.		0.26-0.30
27/07/85	THM	Collected dosimeters, dismantled site.		0.30-0.34

MONITORING STATION SUMMARY

STATION ID: TG10

STATION TYPE: Tailings Gamma

STATION LOCATION: Gunnar Central

STATION DESCRIPTION: Located at mat site M10.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
1/05/85	PF, THM	Installed stake and 2 dosimeters.	Ground very hard, had to use pick axe.	0.20-0.22
22/06/85	THM	Site maintenance.		0.20-0.23
27/07/85	THM	Collected dosimeters, dismantled site.		0.24-0.28

MONITORING STATION SUMMARY

STATION ID: TG11 STATION TYPE: Tailings Gamma STATION LOCATION: Gunnar Central

STATION DESCRIPTION: Located at mat site M11.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
1/05/85	PF, THM	Installed stake and 2 dosimeters.	Ground very hard, had to use pick axe.	0.24-0.28
22/06/85	THM	Site maintenance.		0.32-0.35
27/07/85	THM	Collected dosimeters, dismantled site.		0.29-0.32

MONITORING STATION SUMMARY

STATION ID: TG12 STATION TYPE: Tailings Gamma STATION LOCATION: Langley Bay

STATION DESCRIPTION: Located at mat site M12.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
1/05/85	PF, THM	Installed stake and 2 dosimeters.	Ground very hard, had to use pick axe.	0.18-0.20
22/06/85	THM	Site maintenance.		0.22-0.26
27/07/85	THM	Collected dosimeters, dismantled site.		0.22-0.26

MONITORING STATION SUMMARY

STATION ID: TG13 STATION TYPE: Tailings Gamma STATION LOCATION: Langley Bay

STATION DESCRIPTION: Located at mat site M13.

STATION HISTORY:

Date	Person	Action	Remarks	Spot γ (mR/hr)
1/05/85	PF, THM	Installed stake and 2 dosimeters.	Ground very hard, had to use pick axe.	0.12-0.14
22/06/85	THM	Site maintenance.	1 m gamma dosimeter had fallen from stake onto mat.	0.48-0.52
27/07/85	THM	Collected dosimeters, dismantled site.		0.47-0.54

MONITORING STATION SUMMARY

STATION ID: WRG1　　STATION TYPE: Waste Rock　　STATION LOCATION: Waste Rock Pile

STATION DESCRIPTION: Located at mat site WR1.

STATION HISTORY:

Date	Person	Action	Remarks	Spot v (mR/hr)
1/12/85	PF, THM	Installed stake and 2 dosimeters.		0.08-0.12
24/06/85	THM	Site maintenance.		0.08-0.12
27/07/85	THM	Collected dosimeters, dismantled site.		0.08-0.11

MONITORING STATION SUMMARY

STATION ID: WR1 STATION TYPE: Radon Flux (mat) STATION LOCATION: Waste Rock Pile

STATION DESCRIPTION: Located on northern portion of waste rock pile.

STATION HISTORY:

Date	Person	Action	Remarks	Spot ν (mR/hr)
1/12/85	PF, THM	Prepared site, installed 5 cups and mat.	Site picked in part for its lack of remarkability - it was very typical of the pile.	0.08-0.12
24/06/85	THM	Collected and replaced 5 cups.		0.08-0.12
27/07/85	THM	Collected 5 cups, dismantled site.		0.08-0.11

Volume

4

BBT GEOTECHNICAL CONSULTANTS LTD.

CONTRACT REPORT NUMBER: OSQ84-00195
VOLUME 4
APPENDIX 3

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
CONTRACT NO. 15SQ.2341-4-1674X
VOLUME 4 - APPENDIX 3
TAILINGS SOLIDS AND SURROUNDING SOILS

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BBT PROJECT NO. S84-1750

MARCH 31, 1986

EXECUTIVE SUMMARY

The fieldwork for the tailings solids and surrounding soils portion of the study was conducted in conjunction with the installation of monitor wells for the groundwater component. The selection of test hole locations was, therefore, made to provide the best areal coverage possible to satisfy both requirements.

The initial concept for the fieldwork as contained in the proposal was to use a track mounted auger drill mobilized by barge. The contract was not awarded until after freeze up in late October 1984 however, and as a result, this method of drilling had to be abandoned. In addition, the possibility for an overland winter road to be constructed to Uranium City in 1985 was uncertain and in any event the timing would have been too late. Various types of aircraft mobilized equipment were considered in conjunction with the Scientific Authority and it was decided to use a locally available vibratory drill which could be moved by helicopter.

The vibratory drill was able to complete an adequate number of test holes to satisfy the project objectives within the project budget. The disadvantages of the drill were that a complete stratigraphic log of the test holes was not possible and the types of piezometer installations was restricted. Mechanical problems with the drill affected the number of installations in some of the campaigns. Fieldwork was performed in three campaigns in November 1984, March 1985 and June 1985. The vibratory drill was used for the November and March campaigns. Hand auger equipment was used for the June campaign. In summary, 65 test holes were drilled with the drill rig for an approximate total depth of 420 m. In addition, 25 test holes were dug or augered by hand.

All samples were visually logged in the field, placed in suitable containers, labelled and shipped to Saskatoon for distribution to the various testing laboratories. Geotechnical testing was performed by BBT and consisted of moisture content, density, Atterberg limit, grain size, triaxial, consolidation, and permeability tests. Geochemical and radionuclide testing was performed by IEC BEAK Analytical Laboratories Ltd. and The Saskatchewan Research Council. Two samples were also tested for rare earths by X-ray Assay Laboratories Limited.

The general stratigraphy encountered in the test holes consisted of tailings, organic materials, lacustrine clayey silts or silty clays, and bedrock. The depth of tailings varied up to greater than 14 m at Gunnar Main, 3 to 4 m at Gunnar Central and 2 to 4 m in Langley Bay. Peat or organic clay was often noted at the interface between the tailings and native soil. The underlying soil was a silty clay or clayey silt. The thickness of this deposit varied considerably from 0.5 to 9.4 m at Gunnar Main, 3 to 6 m at Gunnar Central and 8 m to greater than 16 m in Langley Bay. Bedrock was defined as abrupt casing refusal.

The tailings graded from a fine to medium, poorly graded sand near the spigot location on Gunnar Main, to silty sand, to silt, to silty clay with increasing distance from the spigot. There was also a tendency for increasing fineness with depth. Gunnar Main was primarily poorly graded (SP) sand at the south side grading to silty sand and silt at the north side. Gunnar Central was predominantly silty sand and silt. The Langley Bay tailings were predominantly silt and silty clay with only minor amounts of silty sand.

The laboratory hydraulic conductivity results for the tailings varied from 1E-03 to 1E-06 cm/sec. with the higher values representing the coarser areas.

The native clayey silts and silty clays were generally saturated with relatively low shear strengths. The material varied from low to highly plastic depending on the silt content. The laboratory permeability values for these materials varied from 1E-06 to 1E-10 cm/sec.

The chemistry of three components of the tailings solids were determined. These components were the water soluble fraction, the acid leach fraction, and the residue remaining after leaching.

THE GUNNAR FIELD STUDY

The Gunnar Field Study consists of 10 volumes, each published separately. Volumes 2 to 10 are supplements to Volume 1, written as Appendices 1 to 9.

The 10 volumes are:

- Volume 1 - Summary Report
- Volume 2 - Test Procedures and QA/QC Program (Appendix 1)
- Volume 3 - Atmospheric Studies (Appendix 2)
- Volume 4 - Tailings Solids and Surrounding Soils (Appendix 3)
- Volume 5 - Groundwater (Appendix 4)
- Volume 6 - Surface Water (Appendix 5)
- Volume 7 - Biology (Appendix 6)
- Volume 8 - Waste Rock (Appendix 7)
- Volume 9 - Human Exposure Conditions (Appendix 8)
- Volume 10 - Permafrost (Appendix 9)

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4.0 INTRODUCTION

The tailings solids and surrounding soils portion of The Gunnar Field Study included a field sampling program and a laboratory testing program to provide a complete physical (geotechnical), geochemical and mineralogical characterization of the tailings. It also included a sampling program, classification and some limited geotechnical and geochemical testing of the surrounding soils. Figure No. 4.1 is a plan which shows the key areas of the mine/mill complex.

The field test drilling and sampling program was conducted under the direct supervision of BBT Geotechnical Consultants Ltd. The following laboratories were used for the laboratory testing program:

Geotechnical Testing - BBT, Saskatoon, Saskatchewan
- BBT, Edmonton, Alberta
Chemical - IEC BEAK, Mississauga, Ontario
Radionuclides - Saskatchewan Research Council, Saskatoon, Saskatchewan
Check Tests and Replicates - Monenco, Calgary, Alberta
Rare Earths - X-Ray Assay Laboratories Limited - Don Mills, Ontario.

Soil samples were recovered from a drilling program conducted in conjunction with the groundwater portion of the study. The field program was therefore selected to maximize the information for both study components. Major field campaigns were conducted in November 1984, March 1985 and June 1985. Laboratory testing was conducted from January to October 1985.

This appendix provides the following information:

- Historical Data and Geological Setting
- Sampling Plan
- Rationale for the Plan
- Field and Laboratory Procedures Including QA/QC
- Detailed Data Presentation and Discussion of Results.

The appendix is a factual presentation of the work performed and results achieved. In accordance with the scope of work, no attempt has been made to interpret data.

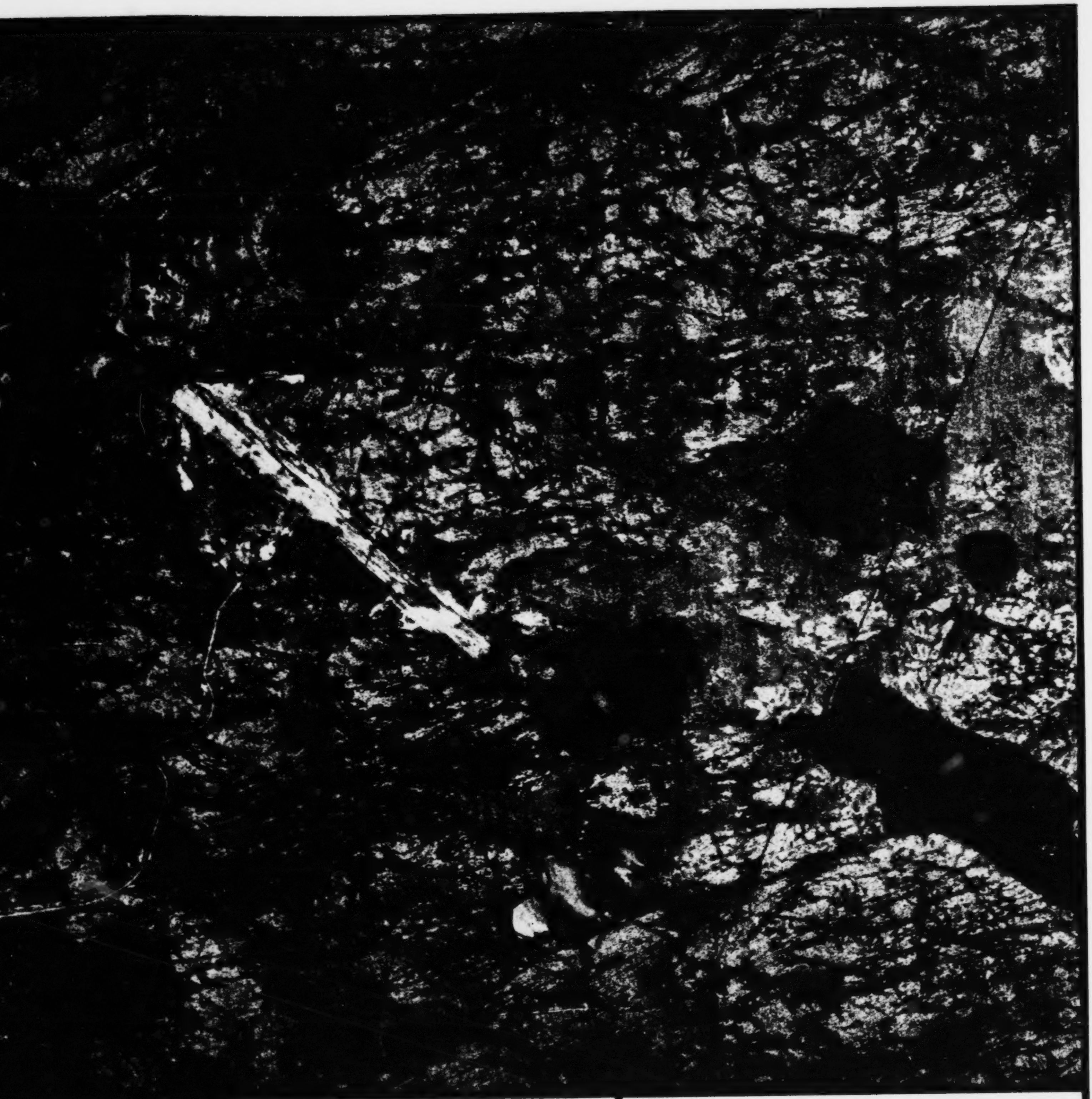
A special requirement of the project was the preparation of detailed contour plans of the entire mine/mill complex area. These plans relate to many of the technical components of the study, but because of the their bulk, are included in this volume only.

4.1 HISTORICAL DATA AND GEOLOGICAL SETTING

4.1.1 Historical Data

The Gunnar minesite is located about 25 km southwest of Uranium City in Northwestern Saskatchewan, at the southern tip of the Crackingstone Peninsula on the north shore of Lake Athabasca. The mine/mill operation was operated from 1955 to 1964. During that period, it is estimated that 4.4 million tonnes of tailings were stored on surface with additional tailings placed underground during the later years of the operation.

The mine was first operated as an open pit and later as a conventional shaft and pillar operation. The ore was ground to 50 percent passing the 0.074 mm sieve (No. 200), processed and piped in a slurry to the Mudford Lake basin (Gunnar Main Tailings on Figure No. 4.1). Included with the tailings slurry was the ion exchange barren. The chemicals used in the processing were sulphuric acid, sodium chlorate and sodium chloride. The tailings slurry was discharged at about 30 percent solids without neutralization. Also included in the discharge to the tailings, was the sewage waste from the townsite. When the Gunnar Main tailings area was filled, a notch was blasted in the rock outcrop at the north end, allowing the tailings to flow into a second depression known as Gunnar Central. When this depression filled, the tailings overflowed into Langley Bay on Lake Athabasca, forming a third tailings body known as Langley Bay Tailings.



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SERGENT, HAUSKINS & BECKWITH
CONSULTING GEOTECHNICAL ENG[illegible]
PHOENIX • ALBUQUERQUE • SA[illegible] FE

SITE PLAN

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1:20 000
DATE DEC. '85
DRAWN BY W. T.
APPROVED BY

FIGURE 4.1

4.1.2 Regional Geology

The Gunnar Minesite is located along the north shore of Lake Athabasca at longitude 59 degrees 23 minutes north and latitude 108 degrees 53 minutes east. The topography is rugged and rocky with local relief ranging up to 200 m. Topographic highs usually have a high percentage of outcrop of relatively fresh rock due to the removal of overburden by the recent Pleistocene glaciation. Topographic lows are generally infilled with peat bogs and/or glacio-lacustrine silt or clay.

All the consolidated rocks are Precambrian in age. The surface formations at the site and north of the site, commonly referred to as the Tazin Group, consist of chloritic schists, quartzites, dolomites, amphibolites, and paragneisses of varying composition. The paragneisses in part, grade imperceptibly into granitoid gneisses and massive granite.

To the south of the site, is located the Athabasca Group, a succession of metamorphosed Late Precambrian (Proterozoic) sedimentary rocks. The Athabasca Group ranges from a conglomerate at the base to a sandstone with clay and silt interbeds towards the top. It varies from strongly to weakly cemented and from non-hematized to deeply hematized in some portions.

The Tazin Group metamorphics are for the most part, tightly folded, often steeply dipping, with probably three episodes of folding. The predominant regional trend in the basement rocks is northeast-southwest. The Athabasca sandstone is essentially flat lying with dips usually less than 5°.

The area is highly faulted throughout with the Black Bay Fault striking 45° dipping 59 degrees to 69 degrees southeast, running along the entrance to Langley Bay. Numerous minor faults parallel this structure; the Dome Fault (running through Spring Lake and between Gunnar Main and Gunnar Central), and the Zeemel Fault (running by the ore body) being two local ones. Other minor faults trend east-west and northwest-southwest such as the Iso Fault and the St. Mary's Channel Fault (see Bell, 1955). The major faults are evidenced by wide, now-healed zones of brecciation and shearing.

4.1.3 Site Geology

For the most part, the Gunnar Main and Gunnar Central tailings basins were old lakes confined by bedrock highs. Impoundment dykes were constructed along the east and south sides of Mudford Lake to separate the Gunnar Main tailings from the townsite and to increase storage capacity. An opening was made in the bedrock high, north of Mudford Lake to allow the tailings to flow into the Gunnar Central Basin.

The topographic highs are Precambrian bedrock with a very thin, if any, covering of drift. The topographic lows have been infilled with lacustrine deposits of glacial Lake Athabasca and more recent organic deposits. Schreiner (1984) reports that the occurrence of lacustrine deposits along the north shore of Lake Athabasca is rare and that the deposits generally consist of silts. The findings of this study, however, indicated relatively thick deposits of lacustrine clays in the topographic lows.

Bell (1955), reported that Gunnar Main was the site of a northeast-southwest trending anticline. The western edge of the basin was a cliff like structure (about 5 m high). The eastern edge past the retaining dyke, was a low wet boggy area. The rise between Gunnar Main and the mill was also reported to be an anticline. Several minor quartz veins and basalt dykes of late Archaean or early Proterozoic age were also reported by Bell (1955).

4.2 SAMPLING PLAN

4.2.1 Location and Frequency of Sampling

The sampling of solids was conducted in 3 field campaigns; November 1984, March 1985 and June 1985. Major drilling programs using motorized drilling equipment were conducted in November 1984 and March 1985 only.

The initial concept for the fieldwork as contained in the work proposal was to use a track-mounted auger drill mobilized by barge. The contract was not awarded until after freeze-up in late October, 1984 however, and as a result, this method of drilling had to be abandoned. In addition, the possibility for an overland winter road to be constructed to Uranium City in 1985, was uncertain, and in any event the timing would have been too late. Various types of aircraft mobilized drilling equipment were considered in conjunction with the Scientific Authority and it was subsequently decided to use a locally available vibratory drill which could be moved by helicopter or snow machine (Photograph Nos. 4.1, 4.2, 4.3 and 4.4).

The selection of this type of drill substantially influenced the formation of the sampling plan. These influences were as follows:

1) A complete visual log of the test hole profile was not possible

2) The drill was not capable of drilling precambrian bedrock

3) Sample recovery at depth was very time consuming

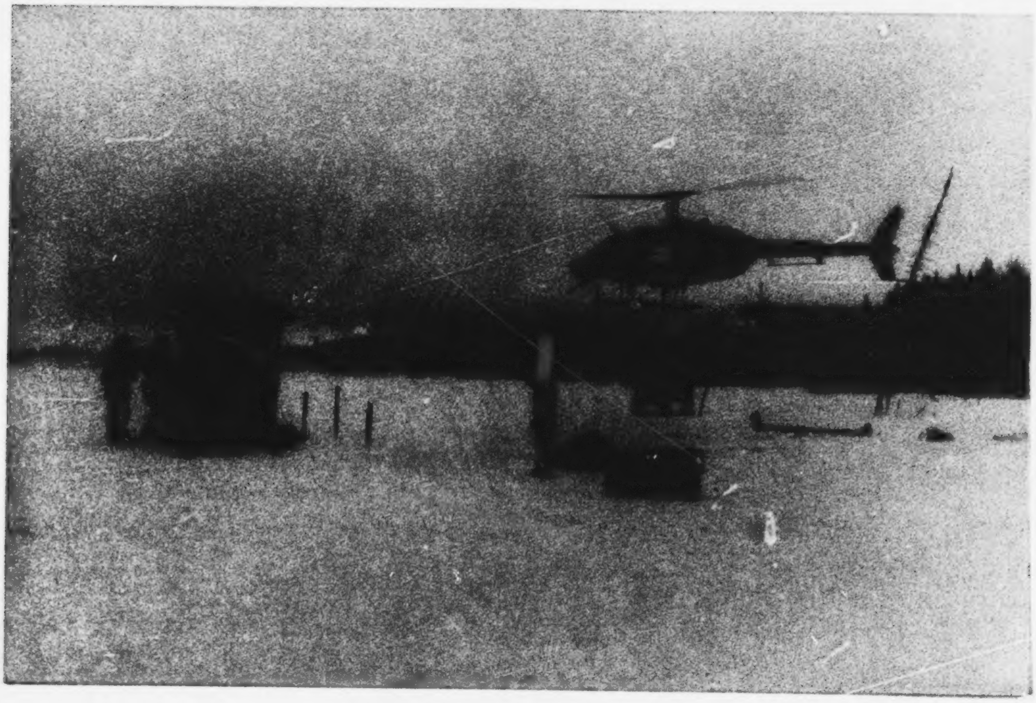
The soil sampling program was performed in conjunction with the installation of piezometers for the groundwater component of the study. Test hole locations were therefore selected to best satisfy the objectives of both study components. Test hole nests (prefix N) generally consisted of 4 to 7 holes at varying depths at one location with a piezometer in each. The principal purpose of the nests was to recover groundwater samples from varying depths. Other test hole locations were primarily designed as single or double piezometer installations. At some locations surface samples only were recovered, while at others, the purpose of the hole was to install thermistors.

The November 1984 campaign was limited to the drilling, sampling and piezometer installation at 5 nest locations to get an overall appreciation of the soils and stratigraphy. Nest Nos. 1, 2 and 3 were installed on Gunnar

PHOTOGRAPH NO. 4.1

Slinging a snowmobile to the Gunnar Minesite from Uranium City.

November 1984



PHOTOGRAPH NO. 4.2

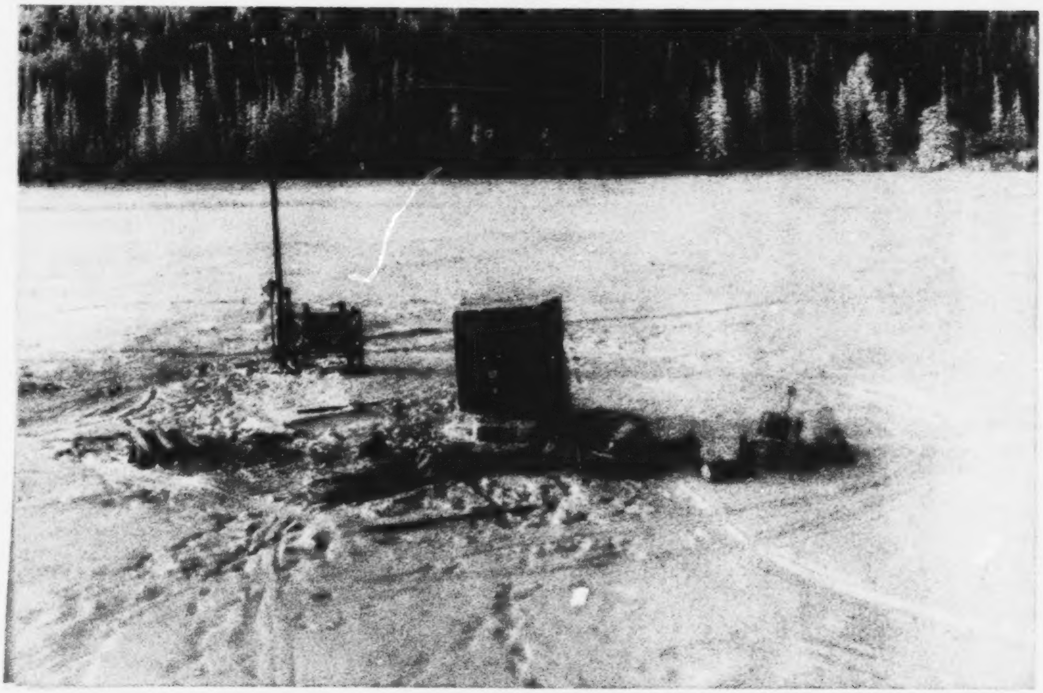
Moving the drill to another site by helicopter.

November 1984

PHOTOGRAPH NO. 4.3

Moving the drill using a double-track snowmobile.

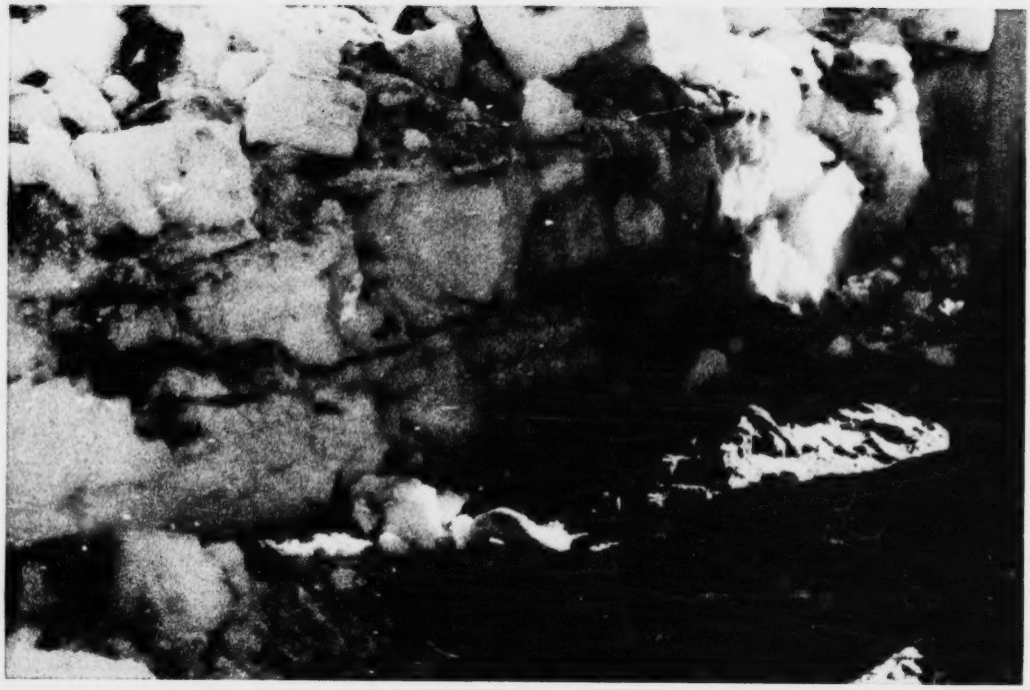
November 1984



PHOTOGRAPH NO. 4.4

Vibratory drill rig at Nest No. 2.

November 1984



PHOTOGRAPH NO. 4.5

Digging out the heavy winter snowfall at Nest No. 1.

March 1985

Main, Nest No. 4 on Gunnar Central and Nest No. 5 on Langley Bay (see Figure Nos. 4.2 and 4.3). Samples of tailings and subsurface soils were taken at regular intervals in the tailings solids. Samples were obtained in each stratigraphic unit where practical. With increasing depth, sampling frequency decreased to maximize the equipment utilization.

The March 1985 campaign was initially designed to complete the test hole program. Mechanical problems with the drill and adverse weather (Photographs Nos. 4.2 to 4.5 inclusive) restricted the number of installations which could be performed. Following is a listing of the proposed March test drilling program and the one which was actually carried out.

	March Campaign	
Location	**Proposed**	**Completed**
Gunnar Main	1 nest	1 nest
Gunnar Main	20 test holes	16 test holes
Gunnar Central	10 test holes	1 test hole
Langley Bay	14 test holes	3 test holes
Waste Rock Perimeter	5 test holes	0
Off Pile Locations	10 test holes	0

The June campaign was performed using hand auger equipment and consisted of 1 test pit and 4 test holes on Gunnar Main, 3 test holes on Gunnar Central and 5 test holes adjacent to the waste rock pile.

Table 4.1 presents a complete listing of the test locations and sampling points. It can be seen from Table 4.1 that wells were not installed in every test hole. In addition, some locations were not sampled at all while others were sampled at the surface only.

Test hole locations are shown on Figure Nos. 4.2, 4.3 and 4.4, and detailed sample locations are shown on the 1:2000 contour plans in Section 4.5.1. The specific sample depths are presented on the test hole summary sheets in Section 4.5.2. All locations and elevations were determined by Prairie Surveys Ltd.

A layer of low permeable clay beneath the tailings was encountered at all 3 main tailings locations. It was decided in consultation with the Scientific Authority that rock coring would not be required. This decision was based on both economic constraints and the consideration that the clay beneath the tailings would effectively provide a seal for the bedrock.

In drilling Nest No. 2 during the November 1984 campaign, frozen ground and ice was encountered at depth indicating the formation of permafrost. Therefore, during the March 1985 campaign, the installation of thermistor strings (as noted in Table 4.1) and the performance of an EM survey were undertaken. These results are reported in Volume 10 Appendix 9 dealing specifically with permafrost.

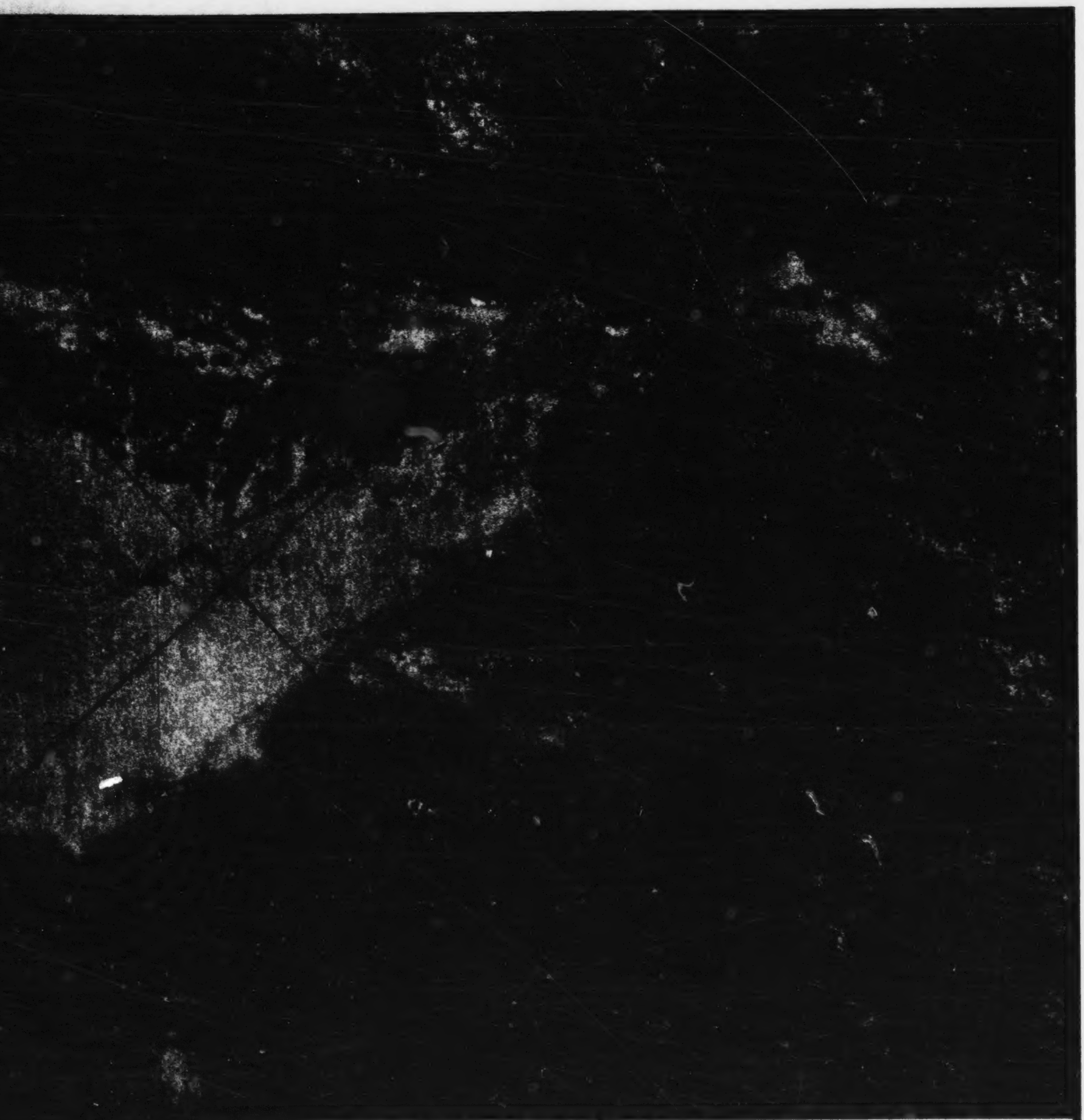
4.2.2 Rationale for Location and Parameters

The sample locations were chosen to provide an areal and vertical representation of the tailings.

The geotechnical parameters required by the terms of reference were moisture content, density, grain size, porosity and hydraulic conductivity (permeability). Specific tests were performed for moisture content, density, grain size and permeability. Porosity can be determined by calculation from the previous results. In addition to the direct project requirements Atterberg limits and specific gravity tests were performed to assist in soil classification. To provide additional information on the tailings, a consolidated undrained triaxial test with pore pressure measurements was performed on an undisturbed silt tailings sample and a consolidation test was performed on a remolded sample of sand tailings.

The chemical and radionuclide testing program was designed to provide a complete characterization of the tailings with respect to chemical and mineralogical composition. The results of the initial tests were used to provide focus for the later stages of the testing program.

GM 11



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GUNNAR MAIN TAILINGS

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1 : 5000	DRAWN BY W.T.	FIGURE 4.2
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LB

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Gunnar Central + Langley Bay Tailings

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

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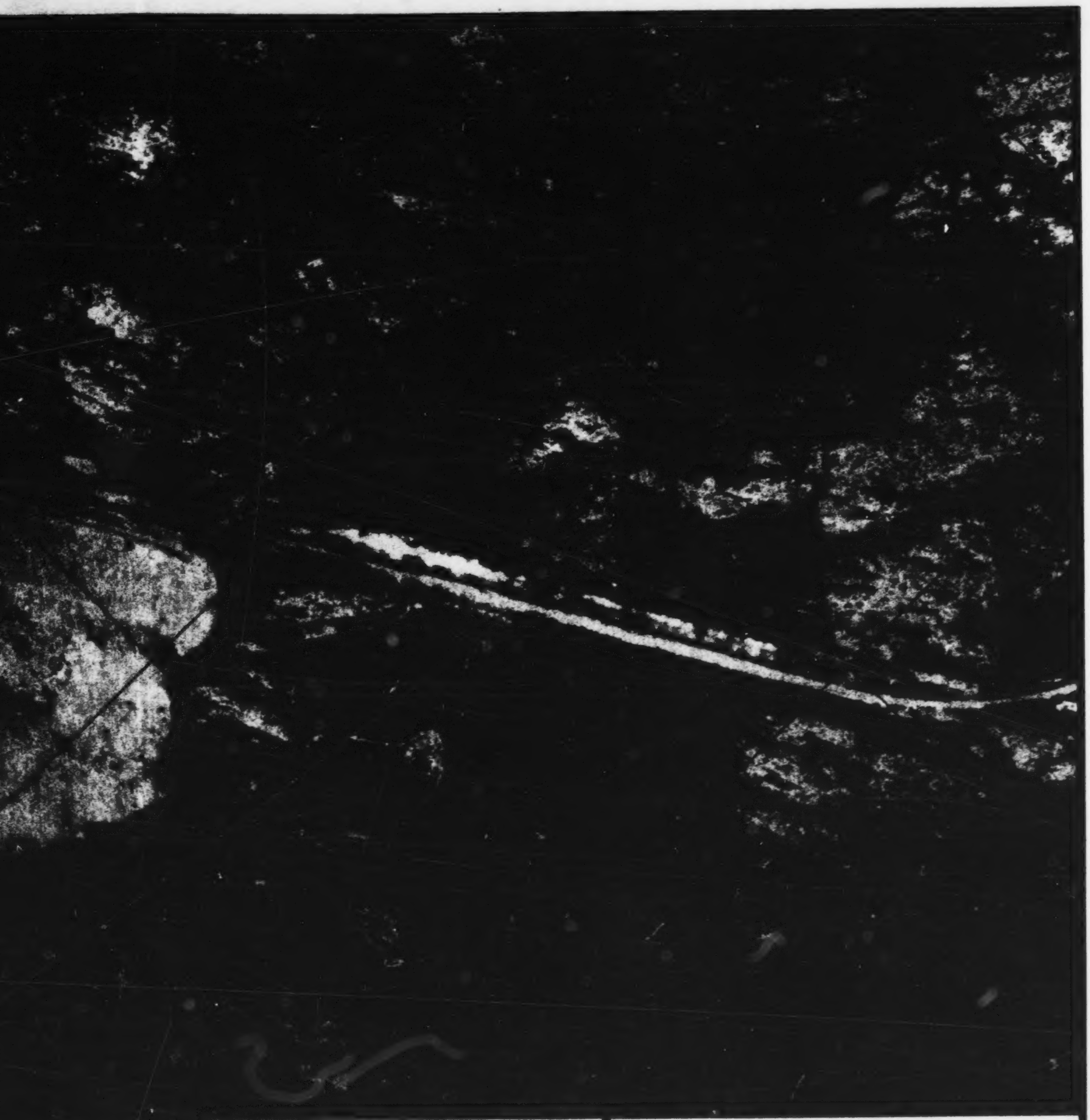
FIGURE 4.3

WASTE
ROCK



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WASTE ROCK PILE

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1: 5000
DATE DEC. '85
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FIGURE 4.4

TABLE 4.1

TEST HOLE AND WELL INFORMATION

Location Identification	Northing (m)	Easting (m)	Relative Elev. (m) Ground	Relative Elev. (m) Casing	Top of Pipe Above Ground Surface (m)	Completion Depth Below Ground Surface (m)	Total Depth of Drilled Hole Below Ground Surface (m)
N1A	1230	3883	106.64	-	Hole Collapsed	Hole Collapsed	7.62
N1B	1231	3883	106.64	107.25**	0.56	3.70	6.10
N1C	1232	3883	106.50	106.88**	0.38(T)	9.67	11.89
N1D	1233	3883	106.29	106.89**	0.60	5.53	7.62
N1E	1227	3890	106.64	106.87	0.23	7.79	13.9
N1F	1227	3890	106.64	107.01	0.37(T)	4.15	4.9
N2A	1336	3702	101.83	102.07**	0.24	4.42	5.49
N2B	1336	3701	101.78	102.06**	0.28	5.72	5.49
N2C	1336	3701	101.79	101.94**	0.15	2.33	2.59
N2D	1336	3700	101.79	101.87**	0.08	1.63	1.83
N2E	1342	3700	101.81	102.17	0.36	7.60	19.6
N2F	1342	3701	101.81	102.29	0.48(T)	5.57	12.2
N2G	1342	3701	101.81	102.24	0.43	5.39	9.9
N2H	1342	3702	101.81	102.13	0.32	3.13	3.3
N2I	1342	3702	101.81	102.18	0.37	2.19	3.0
N2J	1342	3702	101.81	-	No Well	No Well	1.04
N3A	1900	4052	98.59	99.72/ 98.97**	1.13/ 0.38*	2.91	Installed by Vibration
N3B	1900	4052	98.62	99.85/ 98.98**	1.23/ 0.36*	2.81	Installed by Vibration
N3C	1900	4053	98.63	99.60/ 99.04**	0.97/ 0.41*	2.3±	Installed by Vibration
N3D	1899	4053	98.64	99.67/ 99.04**	1.03/ 0.40*	1.01	Installed by Vibration
N3E	1899	4056	98.77	99.03**	0.26	13.35	19.17
N3F	1899	4055	98.78	99.03**	0.25	7.98	8.38
N3G	1898	4054	98.74	99.02**	0.28	2.58	3.96
N4A	2585	4361	83.21	83.59**	0.38	5.41	5.79
N4B	2584	4361	83.08	83.50**	0.42	3.87	4.27
N4C	2585	4362	83.15	83.51**	0.36	2.33	1.98
N4D	2586	4362	83.22	83.98**	0.76	1.28	1.07
N5A	2990	4009	70.78	71.16**	0.38	11.67	16.31
N5B	2990	4009	70.75	71.17**	0.42	3.36	3.35
N5C	2990	4010	70.75	71.12**	0.37	2.10	2.13
N6A	1634	3905	99.87	100.37**	0.50(T)	11.00	11.25
N6B	1634	3905	99.90	100.38**	0.48	5.15	5.20
N6C	1634	3905	99.90	100.23**	0.33	3.93	4.0
N6D	1635	3904	99.89	100.42**	0.53	2.97	3.0
N6E	1635	3903	99.88	100.31**	0.43	1.95	2.0

TABLE 4.1 (continued)

Location Identification	Northing (m)	Easting (m)	Relative Elev. (m) Ground	Casing	Top of Pipe Above Ground Surface (m)	Completion Depth Below Ground Surface (m)	Total Depth of Drilled Hole Below Ground Surface (m)
GM1A	1537	4107	104.35	-	No Well	No Well	No Drilling
GM2A	1426	3928	104.10	-	Thermistors Inst.(T)	5.27	8.4
GM2B	1427	3928	104.10	104.55	0.45	6.97	7.0
GM2C	1425	3928	104.10	104.45	0.35	3.82	3.85
GM2D	1425	3928	104.10	-	No Well	No Well	1.3
GM3A	1214	3631	101.98	-	Thermistors Inst.(T)	4.40	19.8
GM3B	1214	3631	101.98	102.36	0.38	9.90	Installed by Vibration
GM3C	1215	3632	101.98	102.50	0.52	4.14	4.6
GM3D	1215	3632	101.98	102.58	0.60	4.28	4.6
GM3E	1216	3633	101.98	102.48	0.50	4.36	4.6
GM4A	1632	3815	100.92	-	Thermistors Inst.(T)	4.20	4.8
GM4B	1631	3815	100.98	101.38**	0.40	4.67	4.6
GM4C	1632	3815	100.92	-	No Well	No Well	1.22
GM5A	1519	3819	101.46	-	No Well	No Well	No Drilling
GM6A	1543	3863	101.68	101.98	0.30(T)	4.15	11.0
GM6B	1542	3863	101.68	102.10	0.42	2.80	2.8
GM6C	1543	3863	101.68	-	No Well	No Well	1.37
GM7A	1370	3616	99.94	100.61**	0.67	2.0±	Installed By Vibration
GM8A	1673	4034	101.36	-	No Well	No Well	No Drilling
GM9A	1658	4107	101.44	-	No Well	No Well	4.65
GM9B	1658	4107	101.44	101.81	0.37(T)	4.10	4.10
GM9C	1657	4107	101.41	101.71**	0.30	3.54	3.6
GM10A	1171	3988	109.69	-	No Well	No Well	No Drilling
GM11A	1071	3751	104.10	-	No Well	No Well	No Drilling
GM12A	1197	3428	100.95	101.22	0.27	3.00	3.6
GM12B	1197	3428	100.95	101.35	0.40	1.77	1.8
GM13A	1444	3466	100.60	100.92	0.32	6.86	9.8
GM13B	1444	3467	100.60	100.98	0.38	3.12	3.2
GM17A	1781	3893	99.71	-	No Well	No Well	7.15
GM17B	1781	3894	99.68	100.02**	0.34	3.30	3.4
GM17C	1780	3894	99.60	99.95**	0.35	1.80	1.8
GM18A	1430	3678	100.34	–	No Well	No Well	No Drilling

TABLE 4.1 (continued)

Location Identification	Northing (m)	Easting (m)	Relative Elev. Ground (m)	Relative Elev. Casing (m)	Top of Pipe Above Ground Surface (m)	Completion Depth Below Ground Surface (m)	Total Depth of Drilled Hole Below Ground Surface (m)
GM19A	1563	3667	101.24	-	No Well	No Well	3.9
GM19B	1563	3667	101.00	101.65**	0.65	3.70	3.7
GM19C	1563	3668	101.41	101.99**	0.58	2.47	2.5
GM20	1550	3870	100.0±	-	Test Pit	No Well	1.43
GM21	2082	4185	99.9±	-	0.1	0.90	1.00
GM22	1270	4136	104.5±	-	0.2	0.80	0.90
GM23	1646	4200	99.5±	-	0.1	0.90	1.00
GM24	1648	4366	98.5±	-	0.1	0.90	1.10
GM25	1670	3938	99.2±	-	No Well	No Well	No Drilling
GC5A	2596	4400	83.11	-	No Well	No Well	9.8
GC5B	2597	4400	83.11	83.35	0.24	3.10	4.0
GC5C	2597	4400	83.11	83.43	0.32	3.81	4.4
GC6	2560	4546	82.9±	-	No Well	0.02	No Drilling
GC7	2630	4405	82.1±	-	No Well	0.01	No Drilling
GC8	2628	4340	82.2±	-	No Well	0.01	No Drilling
LB2A	2813	3877	69.89	-	No Well	No Well	19.8
LB2B	2813	3877	69.89	70.24	0.35	3.59	3.6
LB2C	2813	3878	69.89	70.29	0.40	3.38	4.2
LB3A	3192	4154	69.84	70.22	0.38	1.40	1.4
LB3B	3192	4154	69.84	-	No Well	No Well	13.1
LB3C	3191	4154	69.84	70.24	0.40	3.60	3.7
LB7A	3119	4105	69.89	-	No Well	No Well	11.3
LB7B	3119	4105	69.89	70.24	0.35	4.10	4.2
LB7C	3119	4106	69.89	70.22	0.33	2.13	2.2
WR1	465	4555	69.0±	-	0.1	0.90	1.00
WR2	465	4727	72.8±	-	0.1	0.90	1.00
WR3	622	4790	72.5±	-	0.1	0.90	1.00
WR4	718	4750	73.8±	-	0.3	0.80	0.90
WR5	750	5030	72.0±	-	0.1	1.00	1.10

* Cut Back From Original Length on 03/08/85.

** Elevations Surveyed. Remaining Elevations Were Calculated By Adding the Pipe to the Ground Elevation.

± Elevations were estimated from the contour plans.

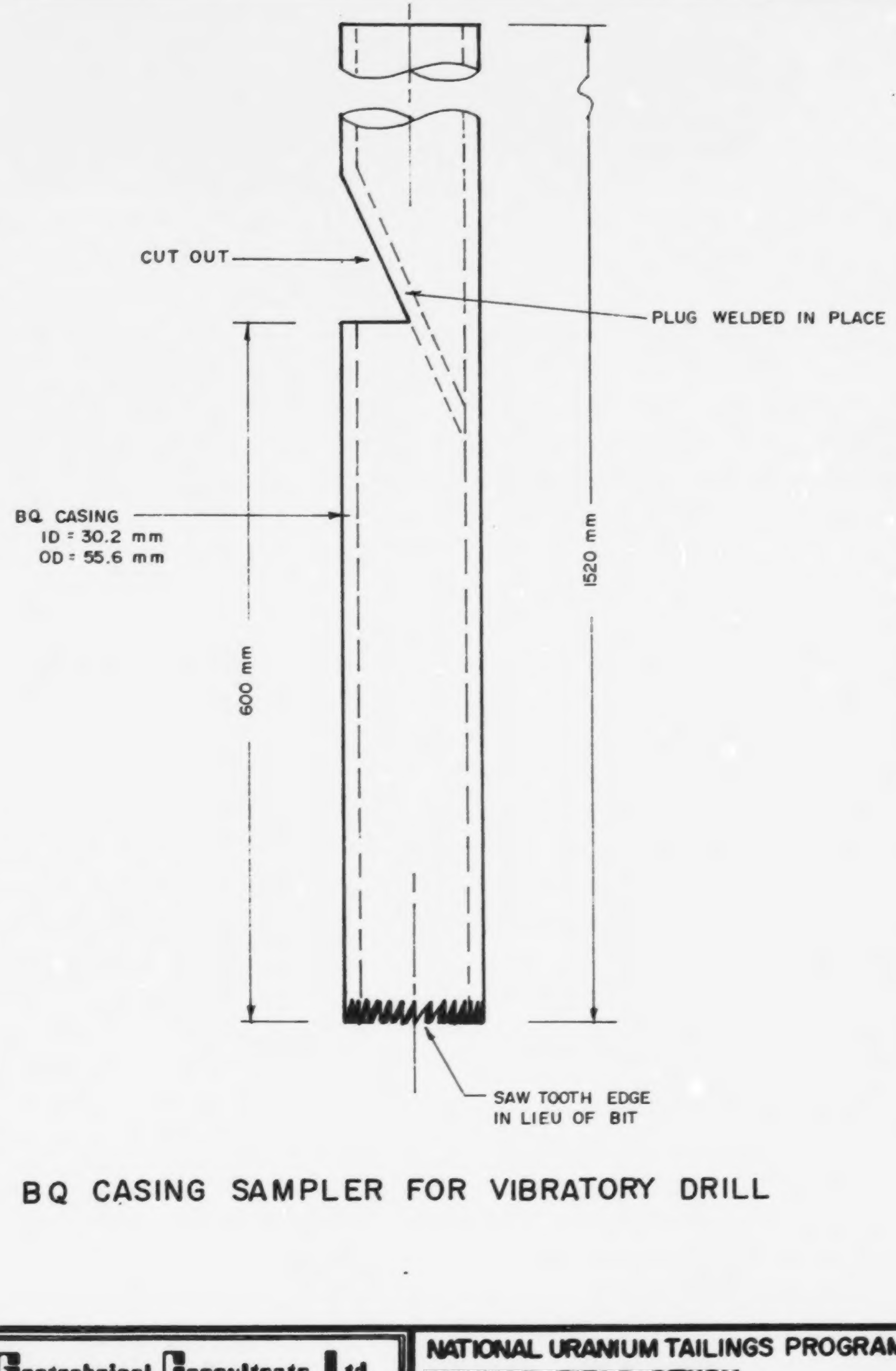
(T) - Thermistor String Installed.

4.3. METHODS AND PROCEDURES

4.3.1 Materials and Methods

The remote site was well suited to the use of a light vibratory drill rig. The drill rig was moved by slinging it by a helicopter and where practical, by towing it with a large snowmobile (Photograph Nos. 4.2 and 4.3). The drill rig was powered by a 2 cylinder snowmobile engine and advanced the hole using BQ casing. The rig performed well when it was running. Unfortunately, equipment difficulties caused considerable downtime, particularly in the March 1985 campaign.

The drill rig utilized BQ casing in 1.52 m and 3.05 m lengths together with a carborundum bit. It was soon established that by cutting a saw toothed edge on the end of the casing to use as a bit, the drilling rates in the tailings substantially improved. The standard sampler was a 1.52 m length of BQ casing with a clean out slot 0.6 m from the bottom with a closed plug (see Figure No. 4.5). The casing was advanced by rotation and vibration with cuttings flowing up the inside of the barrel, out the slot and then outwards between the core barrel and the side wall of the test hole. When a sample was required the casing was withdrawn and the soil removed from the 0.6 m zone between the tip and the slot. This apparatus provided a relatively uncontaminated, disturbed sample of soil about 0.6 m long. The actual sample length varied depending on the distance the casing was advanced. In some instances, only a 0.3 m sample was required. In other cases where the drilling was difficult, the sampler would be retrieved and emptied at more frequent intervals. Drilling in medium grained sand above the groundwater table was slow as the sand, particularly with depth, would bind the sampler and the casing. Alternately, drilling below the water table in loose sand, silt or clay was rapid. Sample recovery from depth required removing all the casing, emptying the sampler and replacing all the casing. Thus, samples were recovered from depth with discretion.



CUT OUT
PLUG WELDED IN PLACE
BQ CASING
ID = 30.2 mm
OD = 55.6 mm
1520 mm
600 mm
SAW TOOTH EDGE
IN LIEU OF BIT

BQ CASING SAMPLER FOR VIBRATORY DRILL

BBT Geotechnical Consultants Ltd. BBT GEOTECHNICAL CONSULTANTS LTD.	NATIONAL URANIUM TAILINGS PROGRAM GUNNAR FIELD STUDY SOUTH OF URANIUM CITY, SASKATCHEWAN			
	SCALE N.T.S	DATE DEC.'85	DRAWN BY N.T.	FIGURE 4.5

Undisturbed Shelby tube samples were attempted at various depths in several of the test holes during the March campaign only. The Shelby tubes were 50 mm in diameter and were specially coated on the inside with teflon to minimize friction during sampling and extrusion. The Shelby tube was fastened to the BQ casing using a BQ adaptor. The casing was inserted in the test hole and the sample was attempted using down pressure only to achieve penetration. Often, down pressure was not sufficient and some vibration was required to achieve adequate penetration. The casing and Shelby tube sampler were then withdrawn. In some cases, the casing was binding in the test hole and vibration was required to remove it. The sample was occasionally lost and when this occurred, it was noted on the test hole log. The densification effect of the vibratory drill in advancing the test hole aided in maintaining an open test hole below the water table for a short period of time. Shelby tube samples were only attempted when the amount of slough material in the bottom of the hole was not significant.

The 56 mm outside diameter of the test hole dictated that 32 mm inside diameter Schedule 40 PVC pipe (50 mm outside diameter) be used for the piezometers. Special piezometer tips were made up with a rigid permeable screen 127 mm long protected by a 50 mm outside diameter PVC drive tip. The assembly could then be installed in the open drilled hole (after the casing had been removed). Once inserted into the test hole, the assembly was vibrated or pushed into place. The drill head was too light, however to achieve substantial penetration, even with considerable vibration. The test hole was allowed to collapse around the riser pipe or tailings sand was placed around the pipe. Piezometer installation details are included in Volume 5, Appendix 4 - Groundwater.

4.3.2 Sample Preservation and Shipping

The disturbed samples were double bagged with a label between the bags. The bags were sealed by knotting. The undisturbed Shelby tube samples were labeled on the outside and the ends were sealed with hot wax to prevent moisture loss.

All of the samples were transported to Uranium City in above freezing conditions. A list of samples was prepared and the samples were shipped to Saskatoon for distribution to various laboratories for testing. When the samples were distributed to each laboratory, they were accompanied with a Sample Transmittal Sheet indicating the testing to be performed. The documentation of the samples in this manner minimized confusion.

4.3.3 Laboratory Procedures

The laboratory procedures used for the chemical, radionuclide, and rare earth testing are discussed in detail in Volume 2, Appendix 1 and are not reproduced in this volume. The procedures described in this section pertain to geotechnical testing only. Where the procedures used were in accordance with a standard procedure, such as described by ASTM, reference will be made to it and the only discussion will be with reference to deviations from that procedure.

Classification System

Unified Soil Classification System (USCS) with modifications as proposed by the Prairie Farm Rehabilitation Administration (PFRA). The main modification is the inclusion of a medium plasticity range for cohesive soils (Liquid Limit 30 to 50).

Moisture Content

ASTM D2216-80 "Laboratory Determination of Water (Moisture) Control of Soil Rock and Soil-Aggregate Mixtures".

Liquid and Plastic Limits

ASTM D4318-84 "Liquid Limit, Plastic Limit and Plasticity Index of Soils".

Specific Gravity

ASTM D854-83 "Specific Gravity of Soils".

Hydrometer Grain Size

ASTM D422-63 (Reapproved 1972) "Particle Size Analysis of Soils". Flocculation tended to be a problem in some of the finer grained samples and as a result, very high dosages of dispersing agent were required for these samples. Specific gravity tests were performed to determine the magnitude of the correction to be applied for these high dosage rates.

Relative Density

ASTM D4253-83 "Maximum Index Density of Soils Using a Vibratory Table", ASTM D4254-83 "Minimum Index Density of Soils and Calculation of Relative Density". The size of the sample was not sufficient to permit use of the specified sample size (2830 cm^3) and as a result spacer plates were used in the mold. Also, the vibratory table used was not in strict accordance with the requirements.

Dry Density

Density measurements in saturated sensitive silty soils are normally very difficult to obtain. With the limitations of the drilling equipment, it was particularly difficult on this project. Three methods were used which are described as follows:

BQ Casing Samples (BQ) - The volume of the BQ casing sampler was determined by measurement. When a bulk density determination was desired the sampler was advanced into the ground its full penetration. It was withdrawn and all soil contained in the sampler was retrieved and placed in a plastic bag. The bags were taken to BBT's Saskatoon Laboratory, where the total mass of wet soil and dry soil was determined. The density value was then obtained by dividing the total dry mass of the soil by the volume of the sampler.

Shelby Tube (ST) - In the laboratory, the wax was removed from the ends of the Shelby tubes, the ends of the sample were trimmed, the length of sample was measured, and then the sample was completely removed from the tube and placed in a bowl. The total mass of the sample was then determined on both a wet and dry basis. The density was determined by dividing the mass of dry soil by the volume the sample occupied in the tube.

Insitu Measurements (IN) - Insitu density measurements were made by NUTP personnel in August. The tests were made in shallow hand excavations. A tin can with a known volume was pushed into the soil to the full height of the tin, and then extracted. The soil recovered in the tin plus any soil remaining in the hole within the dimensions of the tin was placed in a bag. The density was then determined by obtaining the dry mass of soil in the laboratory and dividing it by the volume of the tin.

Permeability (Hydraulic Conductivity)

Four different procedures were used for determining the coefficient of permeability in the laboratory. The four procedures used were as follows:

Proctor Mold (PO) - These tests were performed on disturbed samples. The sample was dried and then placed in a 100 mm Proctor mold with hand tamping. Porous stones were placed on each end and specially designed end plates with gaskets were attached. The sample was saturated and a falling head test performed. The test was re-run until a constant permeability value was obtained. The sample height was measured after the test was complete in order to determine the density of the sample.

Shelby Tube (ST) - In this procedure, Shelby tube samples were prepared by cutting off the ends of the tube slightly beyond the end of the sample. Any loose material was trimmed from the ends of the sample, the length was measured and then the sample was contained by a spring loaded porous stone, stopper arrangement. The stoppers were sealed to prevent moisture loss and then the sample was saturated. After saturation, a constant head permeability test was performed using the cell pressure apparatus from a triaxial frame.

Triaxial (TA) - This test was performed on undisturbed samples extruded from the Shelby tube and set up in a triaxial cell with a flexible membrane. The samples were saturated and a constant head test performed similar to the Shelby tube samples.

Consolidation (CON) - In this procedure, the coefficient of permeability was back calculated from a consolidation test performed on a remolded sample.

Triaxial

One sample was tested in the triaxial apparatus using the consolidated undrained procedure with pore pressure measurements. One confining pressure was used. The sample tested was an undisturbed sample extruded from a Shelby tube.

Consolidation

ASTM D2435-80 "One-Dimensional Consolidation Properties of Soil". This test was performed on a remolded sample.

4.3.4 QA/QC, Precision, Accuracy

QA/QC, precision and accuracy of chemical and radionuclide tests is discussed in detail in Volume 2, Appendix 1.

In general, the NUTP "Tailings Sampling Manual" was followed for field procedures. Detailed field notes were kept describing sample locations, physical conditions of sample, etc. For sampling and/or insitu testing which may be viewed as non-routine, professional judgement of the key team members was used in the field. The field identifications, other relevant observations and rationale for the judgement were noted.

Sample depth in the field was determined by measuring the length of BQ casing in the ground. This would be checked as it was being inserted and as it was being withdrawn, thus providing a double check on the sample depth. All sample depths discussed in this report are to the top of the sample and are estimated to be accurate within ±0.15 m. Where soil interfaces are shown on the test hole log, in most cases the position was inferred from the classification of adjacent samples and the degree of difficulty in drilling. It is estimated that the accuracy of these interfaces may be no more than ±0.6 m. In some cases, no inference at all was possible as to the position of the interface between tailings and underlying soil.

The sample locations were identified with the following prefixes:

GM - Gunnar Main
GC - Gunnar Central
LB - Langley Bay
WR - Waste Rock
N - Nest of Monitor Wells

Individual test holes were numbered consecutively for each area. Where more than one test hole was sampled at one location, the locations were supplemented with a letter, e.g. GM13A. Soil samples were either bagged (B) or sampled by a thin walled Shelby tube (T) and were identified by "S" for soil. The sample was also identified by the date that it was sampled according to the format 841124 for November 24, 1984. Thus a sample was identified by the location, type and date. For example, GM13A-S3T-850319 was sampled at Test Hole No. 13, on Gunnar Main on March 19, 1985 and was the third soil sample which was recovered using a thin walled Shelby tube. No problems were experienced with confusion over sample location or depth. A master list of each days samples was prepared in Uranium City after returning from site.

The Shelby tube samples were all taken with clean tubes not previously used on the project, and as such, did not suffer from cross contamination of the sampling equipment. The BQ casing sampler was only hand cleaned between usages and therefore the potential for some minor contamination of these samples does exist.

With respect to the precision or accuracy of laboratory test results, the tests must be separated into 2 groups as follows:

1) Tests where sample disturbance is of no importance.

2) Tests where sample disturbance is critical.

All of the tests performed fall into the first category, except for the density measurements, triaxial tests and permeability tests.

Generally all of the laboratory tests were performed using the precision, accuracy and procedures recommended by ASTM. Therefore, the Group 1 test results will have the precision discussed in the appropriate standard. Generally good agreement was obtained on the duplicate test results using the hydrometer analysis and mechanical screening. The results for Group 2 tests however, where sample disturbance is important, need to be examined further.

The density results obtained could be subject to considerable error, particularly the BQ casing method. Errors in the BQ casing values could result from dilatency or consolidation when the soil entered the sampler and also from loss of soil during the casing removal process. In the case of the Shelby tube samples, the sand and silt tailings were extremely sensitive to disturbance, particularly when saturated. Some moisture loss was noted through the wax seals during transportation and when the wax was removed in the laboratory voids were noted. Both tests therefore, have the potential for the reported results to be higher or lower than the actual. The results ranged from 904 to 2027 kg/m^3. In general, the average results appear to be lower than what would be expected for materials of this specific gravity and grain size. Results lower than or approaching the density of water are extremely suspect.

In some cases, it is estimated that the accuracy of the density test results to represent insitu conditions could be as poor as ±30 percent. This unusually high probability of error is the result of the sensitivity of the soils and the limitations of the field drilling equipment. Much better accuracy was obtained in the cohesive clay samples.

Because of the small sample size and the non-standard vibrating table, the minimum, maximum density values reported should be considered as approximate only.

The potential magnitude of the error in the permeability testing is difficult to quantify. In qualitative terms, ranking the types of tests from most reliable to least reliable, the progression would be:

Triaxial Procedure
Shelby Tube Procedure
Consolidation Procedure
Proctor Mold Procedure

For the tests on disturbed samples, the relevance of the result is dependent on the remolded density as compared to the insitu density. Errors in any particular test result to represent the insitu permeability of that sample could be as high as 1 or 2 orders of magnitude.

An examination of the sample set up for triaxial testing indicated some disturbance, although the sample was completely intact when placed in the cell. The effect of this disturbance was difficult to quantify.

Replicate samples for grain size, Atterberg limit, moisture content and specific gravity were submitted to both BBT's Edmonton and Saskatoon Laboratories. In all cases, the results were within generally accepted limits for consistency when different operators are used to perform the tests. Where a sample was tested twice, both results are reported.

4.3.5 Closeout of Program

No special procedure was undertaken in the test holes which collapsed and in which no piezometers were installed. At the end of the August 1985 field campaign, Don Lush, Technical Coordinator of the study, Grant Feasby, representing NUTP and Ron Barsi of Saskatchewan Environment walked over of the site. It was decided that all the monitor wells would remain in place and would become the responsibility of Saskatchewan Environment.

4.3.6 Topographic Mapping

Topographic mapping was prepared by Prairie Surveys Limited. Timing of the fieldwork did not permit placing control targets and running up-to-date photo coverage due to the presence of snow cover. The mapping was therefore produced by applying current ground survey control to 1:25,000 air photo coverage from 1976. Topographic maps were produced at a scale of 1:5,000 and enlarged to 1:2,000. Figure Nos. 4.6 and 4.7 show site topography at 1:2,000, together with pertinent features of the study area. The contour interval was generally 1 m with a 2 m interval used in the areas with steeper terrain. All survey work was conducted using the top of the turn buckle on a large steel roller drum at the airport as a benchmark. The drum had an assumed elevation of 100.00 m.

4.4 DETAILED TEST RESULTS

4.4.1 Contour Maps

The 1:2000 contour maps are enclosed as Figures Nos. 4.6 and 4.7.

4.4.2 Test Hole Summaries

The following test hole logs present the field test hole logging, monitor well installation details, basic laboratory test results, and sample descriptions. The following notes should be used when reviewing the summaries:

1) The depths are indicated on the logs. Where referenced in the text, the top of the sample is commonly used unless otherwise noted.

2) USCS refers to the Unified Soil Classification System as modified by the Prairie Farm Rehabilitation Administration (PFRA).

3) The symbols w, Pw, and Lw are the moisture contents in percent on a dry solid basis for the insitu condition, the plastic limit and the liquid limit respectively.

4) The dry density is the bulk insitu density.

5) The open screen depth is the distance from the ground surface to the top of the screen.

6) The samples are identified as S2B or S6T indicating that the sample was either a bagged or a Shelby tube sample.

7) Where the moisture content was checked, the second value was included directly under the first value.

8) The height of the standpipe above the ground surface is indicated on the summary sheets in meters.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: NIA

SITE COORDINATES:

N 1230

E 3883

GROUND ELEVATION (m) 106.64

TH - TEST HOLE / TP - TEST PIT: TH

DRILLER / EXCAVATOR: McNeill

COMPLETION DATE: 84/12/01

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m) 7.62

WELL OWNER

INSTALLER

INSTALLATION DATE N/A

CASING ELEV. (m)

CASING LENGTH (m)

CASING DIAMETER (m)

FILTER PACK LENGTH (m)

FORMATION OF COMPLETION:

SEAL (END) DEPTH (m)

OPEN / SCREEN DEPTH (m)

OPEN / SCREEN LENGTH (m)

OPEN / SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							Broke Through at 2.74 m (Frost?)
S1B	4	SM	15.6	1489			SAND, silty, moist, loose, fine, poorly graded (uniform) med. reddish brown.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: NIA

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S2B	7	ML	14.2				SILT, very sandy, moist to wet, stiff, non plastic to low plastic, med. to dark reddish brown. Hole collapsed to 3.96 m.
							Piezometer not installed.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

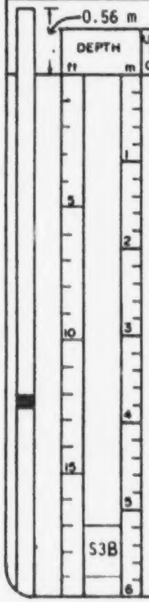
SITE ID Gunnar Main
LOCATION ID: N1B
SITE COORDINATES
N 1231
E 3883
GROUND ELEVATION (m) 106.64

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR McNeill
COMPLETION DATE 84/12/02
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 6.1

WELL OWNER NUTP
INSTALLER G. Bell
INSTALLATION DATE 84/12/02
CASING ELEV. (m) 107.25
CASING LENGTH (m) 4.23
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 3.70
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY



DEPTH	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						Moved 0.6 m N of N1A.
						Piezometer loose in tailings and could move piezometer by pulling up and pushing down.
						Attempted to place piezometer about 6.10 m after drilling was completed. The hole collapsed to about 3.96 m and the piezometer was placed at that depth.
S3B	SM	8.9				SAND, silty, moist, loose, fine poorly graded, (uniform), med. reddish brown.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: NIC
SITE COORDINATES.
N 1232
E 3883
GROUND ELEVATION (m) 106.50

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: McNeill
COMPLETION DATE: 84/12/09
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m): 11.89

WELL OWNER: NUTP
INSTALLER: G. Bell
INSTALLATION DATE: 84/12/09
CASING ELEV. (m): 106.88
CASING LENGTH (m): 10.05
CASING DIAMETER (m): 0.035

FILTER PACK LENGTH (m):
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m):
OPEN / SCREEN DEPTH (m): 9.67
OPEN / SCREEN LENGTH (m): 0.127
OPEN / SCREEN AREA (m²): 0.0203

T 0.38 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	SM	8.2	1410			SAND, moist, med. dense, poorly graded, (uniform), med. reddish brown, some silt.
S2B	SM	7.1	1037			As above.
S3B	SM	8.4	1350		non-plastic	As above, non-plastic, silty.
S4B	SM	12.8				SAND, silty, moist, med. dense fine, poorly graded, med. reddish brown, lost sample (vibrated out of test hole).

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main
LOCATION ID: NIC

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S5B	SM	13.2	1669		non-plastic	As above.
S6B	SM	17.2	1574			As above, silty.
S7B	SM	15.4 16.1	1664			As above, wet, silty.
S8B	SM	14.8	1652			Wet, silty.
S9B	SM	14.9 21.6	1380			Good recovery, very silty.
						NIC was about 3 m SE of NIB. A 9.5 m thermistor was installed with the lowest thermistor at 9.3 m below top of pipe. The thermistor was installed inside the existing piezometer pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID	Gunnar Main	TH - TEST HOLE / TP - TEST PIT	TH
LOCATION ID:	N1D	DRILLER / EXCAVATOR	McNeill
SITE COORDINATES:		COMPLETION DATE:	84/12/10
N	1233	TEST HOLE DIAMETER (m):	0.056
E	3883	TOTAL DEPTH (m)	7.62
GROUND ELEVATION (m)	106.29		
WELL OWNER	NUTP	FILTER PACK LENGTH (m)	
INSTALLER	McNeill	FORMATION OF COMPLETION:	Tailings
INSTALLATION DATE	84/12/10	SEAL (END) DEPTH (m)	
CASING ELEV. (m)	106.89	OPEN/SCREEN DEPTH (m)	5.53
CASING LENGTH (m)	6.13	OPEN/SCREEN LENGTH (m)	0.127
CASING DIAMETER (m)	0.035	OPEN/SCREEN AREA (m²)	0.0203

0.6 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						N1D was 1 m E of N1C.
SIT	SM	7.6	1719		non-plastic	SAND, silty, moist, med. dense, uniformly graded, med. reddish brown.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: N1E - 8.9 m ESE of N1B
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
N 1227
E 3890
COMPLETION DATE 85/03/26
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 13.9
GROUND ELEVATION (m) 106.64

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/26 16:52
SEAL (END) DEPTH (m)
CASING ELEV. (m) 106.87 *
OPEN/SCREEN DEPTH (m) 7.79
CASING LENGTH (m) 8.02
OPEN/SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN/SCREEN AREA (m²) 0.0203

0.23 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	SM	8.3	1226			SAND - frozen to 0.6 m, poorly graded, fine, reddish brown, trace silt, damp below frost. Considerable silt to 1.0 m.
S2B	SP	20.0				
S3B	SP	7.5				
S4B	SP	3.9				
S5B	SP	6.9				A Shelby tube was attempted at 1.5 m, but sample could not be retained and was recovered in a bag.
S6T	SP	5.5	1590	NP	NP	
S7B	SM	7.1				Siltier at 2.5 m.
S8T	SP	7.3	1410			Medium dense to dense at 3.0 m
S9B	SM	8.6	1610			
S10 T	SM	10.9	1459			Hard drilling.
S11 B	SM	14.2				Dark brown portions noted.

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* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main
LOCATION ID: N1E

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S12 T	SM	17.1	1750			Water noted at 6.0 m. Easier drilling.
S13 B	SM	18.5	2027			Damp, moist.
S14 T	SP	14.9	1354			
S15 B	SP	18.9				More coloured, lighter and darker sand grains.
S16 B	SP	19.2				
S17 B	ML	15.8				Silt very sandy, reddish brown moist, stiff, low plastic. Could not drill past 13.9 m, very dense.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: N1F - 0.5 m W of N1E
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES
COMPLETION DATE: 85/03/27
N: 1227
TEST HOLE DIAMETER (m): 0.056
E: 3890
TOTAL DEPTH (m): 4.90
GROUND ELEVATION (m): 106.64

WELL OWNER: NUTP
FILTER PACK LENGTH (m):
INSTALLER: R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE: 85/03/27 10:15
SEAL (END) DEPTH (m):
CASING ELEV. (m): 107.01*
OPEN/SCREEN DEPTH (m): 4.15
CASING LENGTH (m): 4.52
OPEN / SCREEN LENGTH (m): 0.127
CASING DIAMETER (m): 0.035
OPEN / SCREEN AREA (m²): 0.0203

LITHOLOGICAL SUMMARY

T 0.37 m

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W %	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							Hard drilling, could not get below 4.9 m.
							Could not clean out hole due to dry sand. Pipe installed so 6.0 m thermistor ~0.5 m below grade.
							9.5 m string thermistor installed. Lowest at 4.0 m.
							Thermistor string taped to outside of piezometer pipe.
							Piezometer only installed and no samples were recovered.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: N2A
DRILLER / EXCAVATOR: McNeill
SITE COORDINATES
COMPLETION DATE: 84/12/02
N: 1336
TEST HOLE DIAMETER (m): 0.056
E: 3702
TOTAL DEPTH (m): 5.49
GROUND ELEVATION (m): 101.83

WELL OWNER: NUTP
FILTER PACK LENGTH (m):
INSTALLER: G. Bell
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE: 84/12/02
SEAL (END) DEPTH (m):
CASING ELEV. (m): 102.07
OPEN/SCREEN DEPTH (m): 4.42
CASING LENGTH (m): 4.66
OPEN / SCREEN LENGTH (m): 0.127
CASING DIAMETER (m): 0.035
OPEN / SCREEN AREA (m²): 0.0203

LITHOLOGICAL SUMMARY

T 0.24 m

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W %	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							Frost at 0.6 to 0.9 m. Water at 1.5 m.
	S1B	ML	65.4				SILT, very sandy, med. reddish brown, frozen lenses of water, ice from 3.66 to 4.88 m.
	S2B	SM	20.8				SAND, some silt, moist to wet, med. dense, fine, poorly graded, med. to dark brown, trace of clay.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: N2B
DRILLER / EXCAVATOR: McNeill
SITE COORDINATES:
COMPLETION DATE: 84/12/03
N 1336
TEST HOLE DIAMETER (m): 0.056
E 3701
TOTAL DEPTH (m) 5.49
GROUND ELEVATION (m) 101.78

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER G. Bell
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 84/12/03
SEAL (END) DEPTH (m)
CASING ELEV. (m) 102.06
OPEN/SCREEN DEPTH (m) 5.72
CASING LENGTH (m) 6.00
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

T 0.28 m

LITHOLOGICAL SUMMARY

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						Moved 0.6 m E of N2A
S3B	ML	28.2				SILT, very sandy, moist to wet stiff, non plastic, med. reddish brown, frozen from 3.4 m. Drilled to 5.49 m and vibrated the tip down.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: N2C
DRILLER / EXCAVATOR: McNeill
SITE COORDINATES:
COMPLETION DATE: 84/12/03
N 1336
TEST HOLE DIAMETER (m): 0.056
E 3701
TOTAL DEPTH (m) 2.59
GROUND ELEVATION (m) 101.79

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER G. Bell
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 84/12/03
SEAL (END) DEPTH (m)
CASING ELEV. (m) 101.94
OPEN/SCREEN DEPTH (m) 2.33
CASING LENGTH (m) 2.48
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

T 0.15 m

LITHOLOGICAL SUMMARY

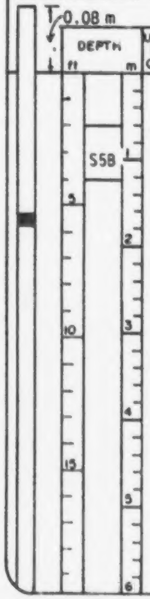
DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION SOIL TYPE AND COLOR
						Moved E 0.6 m from N2B.
S4B	SM	$\frac{25.6}{22.5}$		NP	NP	SAND, very silty, moist, med. dense, poorly graded, medium reddish brown, non-plastic. Vibrated piezometer through slough.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID	Gunnar Main	TH - TEST HOLE / TP - TEST PIT	TH
LOCATION ID	N2D	DRILLER / EXCAVATOR	McNeill
SITE COORDINATES		COMPLETION DATE	84/12/03
N	1336	TEST HOLE DIAMETER (m) :	0.056
E	3700	TOTAL DEPTH (m)	1.83
GROUND ELEVATION (m)	101.79		
WELL OWNER	NUTP	FILTER PACK LENGTH (m)	
INSTALLER	G. Bell	FORMATION OF COMPLETION :	Tailings
INSTALLATION DATE	84/12/03	SEAL (END) DEPTH (m)	
CASING ELEV. (m)	101.87	OPEN / SCREEN DEPTH (m)	1.63
CASING LENGTH (m)	1.71	OPEN / SCREEN LENGTH (m)	0.127
CASING DIAMETER (m)	0.035	OPEN / SCREEN AREA (m²)	0.0203

LITHOLOGICAL SUMMARY



UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					Moved 0.61 m E from N2C.
SM	24.4				SAND, damp, med. dense, uniformly graded, fine size, reddish brown, some silt.
					Vibrated piezometer down through slough.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 3

SITE ID: Gunnar Main
LOCATION ID: N2E
SITE COORDINATES
N 1342
E 3700
GROUND ELEVATION (m) 101.31

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: Wiseman
COMPLETION DATE: 85/03/21
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 19.6

WELL OWNER NUTP
INSTALLER R. Boivin
INSTALLATION DATE 85/03/21 14:30
CASING ELEV. (m) 102.17*
CASING LENGTH (m) 7.96
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 7.60
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY

T — 0.36 m

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	SP	6.2				SAND - frozen, poorly graded, fine, reddish brown, silty.
S2B	SM	24.2				Frost to 0.7 m.
S3B	SM					Attempted tube at 1.5 m. No recovery.
S4T	SM	21.3	1660	NP	NP	Moist.
S5B	SM					Saturated at 3.2 m.
S6T	ML	19.5	1726			SAND, silt at 3.4 m.
S7T	SM	19.8	1725	NP	NP	PP ~ 210 kPa in S7 tube.
S8B	SM	22.9	1749			

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 3

SITE ID: Gunnar Main
LOCATION ID: N2E

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S9T	SM	19.1	1630	NP	NP	
S10 T	ML-OL	21.9	1642	18.2	19.0	Tailings - clay interface at 8.7 m.
			Tailings Interface			
S11 B	OL	57.7				ORGANIC CLAY -odour, very stiff, low plastic, greens, dark greens, black, grey.
S12 T	SM	38.7	1384	NP	NP	S12 - probably slough.
S13 B	SM OL	75.6				S13 - Slough mixed.
S14 T	ML-OL	77.6	904	31.0	41.7	ORGANIC SILT - moist, very stiff, medium plastic, grey. S14 - Slough on top and grey silt at bottom.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 3 OF 3

SITE ID: Gunnar Main

LOCATION ID: N2E

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft.	DEPTH m	Sample	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
50		S15 B	CI	34.0				CLAY - moist, very stiff, medium plastic, grey with green clay also.
	16							
55	17							
	18							
60	19	S16 B	CI	37.6		21.8	33.2	CLAY - moist, stiff, medium to highly plastic, brownish grey.
65	20							Casing refusal at 19.6 m. Piezometer could not be installed past 7.6 m. Thermistor was to be installed but due to lack of depth on piezometer, thermistor removed
	21							
70	22							
75	23							
	24							

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: N2F

DRILLER / EXCAVATOR: Wiseman

SITE COORDINATES:

N 1342

COMPLETION DATE 85/03/22

TEST HOLE DIAMETER (m): 0.056

E 3701

TOTAL DEPTH (m) 12.2

GROUND ELEVATION (m) 101.81

WELL OWNER NUTP

FILTER PACK LENGTH (m)

INSTALLER R. Boivin

FORMATION OF COMPLETION: Tailings

INSTALLATION DATE 85/03/22 16:07

SEAL (END) DEPTH (m)

CASING ELEV. (m) 102.29 *

OPEN/SCREEN DEPTH (m) 5.57

CASING LENGTH (m) 6.05

OPEN / SCREEN LENGTH (m) 0.127

CASING DIAMETER (m) 0.035

OPEN / SCREEN AREA (m²) 0.0203

T — 0.48 m

LITHOLOGICAL SUMMARY

DEPTH ft / S4B / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1T	SM					Biological Samples: SAND - frozen, poorly graded, fine, reddish brown, silty. Sample S4 taken from ground surface as S1 sample may be contaminated.
S2T	SM					Tube S2 pushed from 1.2 m to 1.8 m, no recovery. Pushed to 3.6 m, recovery. Sample would not stay in tube, put into bag
S3T	SM					

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: N2F

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						8.75 m - Thermistor string installed, lowest at 3.44 m below grade. Piezometer could not be vibrated past 5.57 m. Nothing in sampler at 9.2 m, 10.6 m and 12.2 m. Thermistor string taped on outside of piezometer pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main

TH - TEST HOLE / TP - TEST PIT TH

LOCATION ID N2G

DRILLER / EXCAVATOR : Wiseman

SITE COORDINATES

COMPLETION DATE 85/03/22

N 1342

TEST HOLE DIAMETER (m) : 0.056

E 3701

TOTAL DEPTH (m) 9.9

GROUND ELEVATION (m) 101.31

WELL OWNER NUTP

FILTER PACK LENGTH (m)

INSTALLER R. Boivin

FORMATION OF COMPLETION : Tailings

INSTALLATION DATE 85/03/22 16:34

SEAL (END) DEPTH (m)

CASING ELEV. (m) 102.24 *

OPEN / SCREEN DEPTH (m) 5.39

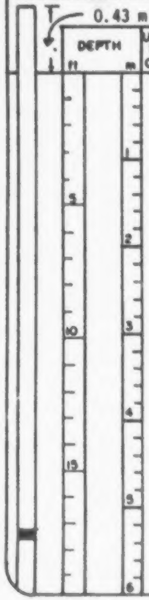
CASING LENGTH (m) 5.82

OPEN / SCREEN LENGTH (m) 0.127

CASING DIAMETER (m) 0.035

OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY



UNIFIED SOIL CLASS.	W %	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					Attempted to install pipe to clay tailings interface but once more the pipe could not be driven to that depth. Nothing in sampler again when pulled from hole. Piezometer only installed. No samples were retrieved.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main

TH - TEST HOLE / TP - TEST PIT TH

LOCATION ID : N2H

DRILLER / EXCAVATOR : Wiseman

SITE COORDINATES

COMPLETION DATE 85/03/23

N 1342

TEST HOLE DIAMETER (m) : 0.056

E 3702

TOTAL DEPTH (m) 3.3

GROUND ELEVATION (m) 101.31

WELL OWNER NUTP

FILTER PACK LENGTH (m)

INSTALLER R. Boivin

FORMATION OF COMPLETION : Tailings

INSTALLATION DATE 85/03/23 12:00

SEAL (END) DEPTH (m)

CASING ELEV. (m) 102.13 *

OPEN / SCREEN DEPTH (m) 3.13

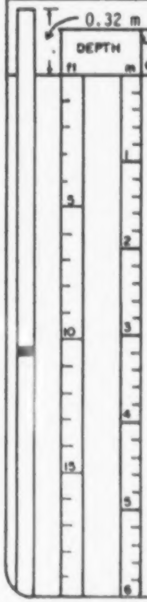
CASING LENGTH (m) 3.45

OPEN / SCREEN LENGTH (m) 0.127

CASING DIAMETER (m) 0.035

OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY



UNIFIED SOIL CLASS.	W %	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					Frost to 0.8 m. Piezometer vibrated last 0.6 m Piezometer only installed. No samples were retrieved.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: N2I
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES
N 1342
E 3702
COMPLETION DATE 85/03/23
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 3.0
GROUND ELEVATION (m) 101.31

WELL OWNER NUTP
INSTALLER R. Boivin
INSTALLATION DATE 85/03/23 12:15
CASING ELEV. (m) 102.13 *
CASING LENGTH (m) 2.56
CASING DIAMETER (m) 0.035
FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 2.19
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY

T
0.37 m
DEPTH
ft
m
5
10
15
1
2
3
4
5
6

UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					Piezometer vibrated last 0.5 m. Piezometer only installed. No samples were retrieved.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main
TH - TEST HOLE / TP - TEST PIT TP
LOCATION ID N2J (Hummock)
DRILLER / EXCAVATOR: D. Lush
SITE COORDINATES
N 1342
E 3702
COMPLETION DATE 85/06/24
TEST HOLE DIAMETER (m): 0.03
TOTAL DEPTH (m) 1.04
GROUND ELEVATION (m) 101.81

WELL OWNER
INSTALLER
INSTALLATION DATE
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)
FILTER PACK LENGTH (m)
FORMATION OF COMPLETION:
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m)
OPEN/SCREEN LENGTH (m)
OPEN/SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

T
DEPTH
ft
m
5
10
15
1
2
3
4
5
6

UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					Loose sandy reddish brown tailings. Frozen below 1.04 m. Hand auger test hole only. No piezometer was installed.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main
LOCATION ID N3A
SITE COORDINATES
N 1900
E 4052
GROUND ELEVATION (m) 98.59

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR Brinkman
COMPLETION DATE 84/12/02
TEST HOLE DIAMETER (m) 0.035
TOTAL DEPTH (m) 3.04

WELL OWNER NUTP
INSTALLER Brinkman
INSTALLATION DATE 84/12/02
CASING ELEV. (m) 98.97 *
CASING LENGTH (m) 4.04
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m) N/A
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m) N/A
OPEN/SCREEN DEPTH (m) 2.91
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

1.13 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						No drilling. No sampling. Piezometer was hammered into the ground. Original extension was 1.13 m and was cut off to 0.38 m on 85/03/08. * Revised after cutoff.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main
LOCATION ID N3B
SITE COORDINATES
N 1900
E 4052
GROUND ELEVATION (m) 98.62

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR Brinkman
COMPLETION DATE 84/12/02
TEST HOLE DIAMETER (m) 0.035
TOTAL DEPTH (m) 2.94

WELL OWNER NUTP
INSTALLER Brinkman
INSTALLATION DATE 84/12/02
CASING ELEV. (m) 98.98 *
CASING LENGTH (m) 4.04
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m) N/A
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m) N/A
OPEN/SCREEN DEPTH (m) 2.81
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

1.23 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						No drilling. No sampling. Piezometer was hammered into the ground. Original extension was 1.23 m and was cut off to 0.36 m on 85/03/08. * Revised after cutoff.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID:	Gunnar Main	TH - TEST HOLE / TP - TEST PIT:	TH
LOCATION ID:	N3D	DRILLER / EXCAVATOR:	Brinkman
SITE COORDINATES:		COMPLETION DATE	84/12/03
N	1899	TEST HOLE DIAMETER (m):	0.035
E	4053	TOTAL DEPTH (m)	1.14
GROUND ELEVATION (m)	98.64		
WELL OWNER	NUTP	FILTER PACK LENGTH (m)	N/A
INSTALLER	Brinkman	FORMATION OF COMPLETION:	Tailings
INSTALLATION DATE	84/12/03	SEAL (END) DEPTH (m)	N/A
CASING ELEV. (m)	99.04 *	OPEN/SCREEN DEPTH (m)	1.01
CASING LENGTH (m)	2.04	OPEN / SCREEN LENGTH (m)	0.127
CASING DIAMETER (m)	0.035	OPEN / SCREEN AREA (m²)	0.0203

1.03 m

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							No drilling. No sampling. Piezometer was hammered into the ground. Original extension was 1.03 m and was cut off to 0.40 m on 85/03/08. * Revised after cutoff.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID:	Gunnar Main	TH - TEST HOLE / TP - TEST PIT:	TH
LOCATION ID:	N3C	DRILLER / EXCAVATOR:	Brinkman
SITE COORDINATES:		COMPLETION DATE:	84/12/02
N	1900	TEST HOLE DIAMETER (m):	0.035
E	4053	TOTAL DEPTH (m)	2.4±
GROUND ELEVATION (m)	98.63		
WELL OWNER	NUTP	FILTER PACK LENGTH (m)	N/A
INSTALLER	Brinkman	FORMATION OF COMPLETION:	Tailings
INSTALLATION DATE	84/12/02	SEAL (END) DEPTH (m)	N/A
CASING ELEV. (m)	99.04 *	OPEN/SCREEN DEPTH (m)	2.3±
CASING LENGTH (m)	3.3±	OPEN / SCREEN LENGTH (m)	0.127
CASING DIAMETER (m)	0.035	OPEN / SCREEN AREA (m²)	0.0203

0.97 m

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							No drilling. No sampling. Piezometer was vibrated into the ground. Original extension was 0.97 m and was cut off to 0.41 m on 85/03/08. * Revised after cutoff.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID Gunnar Main

LOCATION ID N3E

SITE COORDINATES

N 1899

E 4056

GROUND ELEVATION (m) 98.77

TH - TEST HOLE / TP - TEST PIT TH

DRILLER / EXCAVATOR McNeill

COMPLETION DATE 84/12/06

TEST HOLE DIAMETER (m) 0.056

TOTAL DEPTH (m) 19.17

WELL OWNER NUTP

INSTALLER G. Bell

INSTALLATION DATE 84/12/06

CASING ELEV. (m) 99.03

CASING LENGTH (m) 13.61

CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)

FORMATION OF COMPLETION : Clay

SEAL (END) DEPTH (m)

OPEN / SCREEN DEPTH (m) 13.35

OPEN / SCREEN LENGTH (m) 0.127

OPEN / SCREEN AREA (m²) 0.0203

▽ 0.26 m

LITHOLOGICAL SUMMARY

DEPTH ft		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S1B		SM					SAND, moist to wet (at 1.5 m) med. dense, poorly graded, fine size, med. to dark reddish brown, silty, trace of clay, hard just at 3.0 m
		1						
	S2B		SM					
5								
	S3B	2	SM	27.6	1109	NP	NP	
	S4B		SM					As above
10		3						
		4						
15	S5B		ML-OL					As above Tailings interface
	S6B	5	ML	27.0	1104			
	S7B		ML-OL	41.4		23.0	27.9	CLAY, silty, moist, stiff, low plastic, light grey, some rootlets at about 4.6 m, organics at 5.8 m becomes highly plastic at 6.1 m.
		6						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: N3E

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION SOIL TYPE AND COLOR
	S8B		CI	35.3				As above
		7						
	S9B		CI	38.4	1229			As above
25								
		8						
	S10B		CI	39.6	1276	21.9	31.7	As above
		9						
30								
		10						
35								
	S11B	11	CI	36.7				As above
	S12B		CI	30.7				As above
		12						
40								
	S13B	13	CI	39.6		20.8	30.1	As above
45	S14B							
		14	CI	35.5				As above Casing refusal.
		15						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID Gunnar Main
LOCATION ID N3F
SITE COORDINATES
N 1899
E 4055
GROUND ELEVATION (m) 98.78

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR McNeill
COMPLETION DATE 84/12/06
TEST HOLE DIAMETER (m) : 0.056
TOTAL DEPTH (m) 8.38

WELL OWNER NUTP
INSTALLER G. Bell
INSTALLATION DATE 84/12/06
CASING ELEV. (m) 99.03
CASING LENGTH (m) 8.23
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION : Clay
SEAL (END) DEPTH (m)
OPEN / SCREEN DEPTH (m) 7.98
OPEN / SCREEN LENGTH (m) 0.127
OPEN / SCREEN AREA (m²) 0.0203

T 0.25 m

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main
LOCATION ID: N3F

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
25	SIT 8	CI	29.9	1473	18.1	32.9	As N3E

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main
LOCATION ID N3G
SITE COORDINATES
N 1898
E 4054
GROUND ELEVATION (m) 98.74

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR McNeill
COMPLETION DATE 84/12/06
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 3.96

WELL OWNER NUTP
INSTALLER G. Bell
INSTALLATION DATE 84/12/06
CASING ELEV. (m) 99.02
CASING LENGTH (m) 2.86
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 2.58
OPEN / SCREEN LENGTH (m) 0.127
OPEN / SCREEN AREA (m²) 0.0203

T 0.28 m

LITHOLOGICAL SUMMARY

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	ML	24.5	1172			SILT

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Central
LOCATION ID N4A
SITE COORDINATES:
N 2585
E 4361
GROUND ELEVATION (m) 83.21

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR McNeill
COMPLETION DATE 84/12/07
TEST HOLE DIAMETER (m) 0.056
TOTAL DEPTH (m) 5.79

WELL OWNER NUTP
INSTALLER G. Bell
INSTALLATION DATE 84/12/07
CASING ELEV. (m) 83.59
CASING LENGTH (m) 5.79
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Clay
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 5.41
OPEN / SCREEN LENGTH (m) 0.127
OPEN / SCREEN AREA (m²) 0.0203

T 0.38 m

LITHOLOGICAL SUMMARY

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	ML	22.7	1228			SILT, moist, stiff, low plastic, med. reddish brown, sandy, frozen to 0.61 m, trace of clay.
S2B	ML	28.8	1233	27.0	28.7	As above, no sand, unfrozen, some clay at 3.05 to 3.20 m. Tailings Interface
S3B	CL	25.4				CLAY, moist, stiff, low 4.27 m plastic, light grey.
S4B	CL	24.9				As above, organic peat at 4.27m (may have been from above).
S5B	CL	28.3		19.1	27.0	As above. Casing refusal at 5.79 m.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID:	Gunnar Central	TH - TEST HOLE / TP - TEST PIT	TH
LOCATION ID:	N4B	DRILLER / EXCAVATOR	McNeill
SITE COORDINATES		COMPLETION DATE	84/12/07
N	2584	TEST HOLE DIAMETER (m):	0.056
E	4361	TOTAL DEPTH (m)	4.27
GROUND ELEVATION (m)	83.08		
WELL OWNER	NUTP	FILTER PACK LENGTH (m)	
INSTALLER	G. Bell	FORMATION OF COMPLETION	Clay
INSTALLATION DATE	84/12/07	SEAL (END) DEPTH (m)	
CASING ELEV. (m)	83.50	OPEN/SCREEN DEPTH (m)	3.87
CASING LENGTH (m)	4.29	OPEN/SCREEN LENGTH (m)	0.127
CASING DIAMETER (m)	0.035	OPEN/SCREEN AREA (m²)	0.0203

▽ 0.42 m

LITHOLOGICAL SUMMARY

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION SOIL TYPE AND COLOR
						Moved 0.76 m N from N4A
S1T	CL	21.0	1631	17.8	28.6	CLAY, very silty, stiff, low plastic, med. reddish brown
						Tailings Interface
S2T	CI	39.4	1262	22.7	40.1	CLAY, stiff, low plastic, light grey

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TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID:	Gunnar Central	TH - TEST HOLE / TP - TEST PIT:	TH
LOCATION ID:	N4C	DRILLER / EXCAVATOR:	McNeill
SITE COORDINATES:		COMPLETION DATE:	84/12/07
N	2585	TEST HOLE DIAMETER (m):	0.056
E	4362	TOTAL DEPTH (m)	1.98
GROUND ELEVATION (m)	83.15		
WELL OWNER	NUTP	FILTER PACK LENGTH (m)	
INSTALLER	G. Bell	FORMATION OF COMPLETION:	Tailings
INSTALLATION DATE	84/12/07	SEAL (END) DEPTH (m)	
CASING ELEV. (m)	83.51	OPEN/SCREEN DEPTH (m)	2.33
CASING LENGTH (m)	2.69	OPEN/SCREEN LENGTH (m)	0.127
CASING DIAMETER (m)	0.035	OPEN/SCREEN AREA (m²)	0.0203

▽ 0.36 m

LITHOLOGICAL SUMMARY

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION SOIL TYPE AND COLOR
						Moved 0.76 m N from N4B
						No sampling. Piezometer only installed.
						Piezometer vibrated down
						The top of the pipe was broken on 85/03/08 and not repaired. The metal slug was stuck in the pipe and the top was broken trying to retrieve it.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Central
LOCATION ID: N4D
SITE COORDINATES
N 2586
E 4362
GROUND ELEVATION (m) 83.22

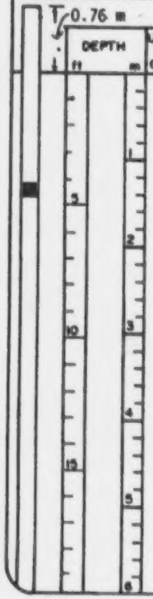
TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: McNeill
COMPLETION DATE: 84/12/07
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 1.07

WELL OWNER NUTP
INSTALLER G. Bell
INSTALLATION DATE 84/12/07
CASING ELEV. (m) 83.98
CASING LENGTH (m) 2.04
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 1.28
OPEN / SCREEN LENGTH (m) 0.127
OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY

0.76 m



DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						Moved 0.61 m N from N4C No sampling. Piezometer only installed. Piezometer vibrated down

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Langley Bay
LOCATION ID: N5A
SITE COORDINATES:
N 2990
E 4009
GROUND ELEVATION (m) 70.78

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: McNeill
COMPLETION DATE: 84/12/08
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 16.31

WELL OWNER NUTP
INSTALLER G. Bell
INSTALLATION DATE 84/12/08
CASING ELEV. (m) 71.16
CASING LENGTH (m) 12.05
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Clay
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 11.67
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

▽ 0.38 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	ML	37.3	1145			SILT, moist, firm, low plastic med. reddish brown, frost to 0.46 m.
5 S2B	ML	31.9	1151			As above, trace of sand.
S3B	ML	34.9	969	24.6	31.9	As above, trace of clay.
10 S4B	ML	50.7		NP	NP	Water was about 2.45 m. As above, non-plastic.
	OL					ORGANIC sand at about 3.51 m
	CI	Tailings Interface				CLAY, moist, stiff, med. plastic, med. grey
15 S5B	CI	64.5				As above, med. grey
S6B	MH	58.1		42.0	50.6	SILT, highly plastic, med. grey

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Langley Bay
LOCATION ID: N5A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S7B	CI	26.9				CLAY, med. plastic, med. grey
25 S8B	CI	33.0				As above
30 S9B	CI	38.4				As above
35 S10B	CI	40.6				As above
40 S11B	CI	39.4		23.0	33.7	As above
45 S12A	CI	37.1				As above
15.70 to 16.31 m	CH	40.4				As above

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Langley Bay
LOCATION ID: N5B
SITE COORDINATES:
N 2990
E 4009
GROUND ELEVATION (m) 70.75

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: McNeill
COMPLETION DATE: 84/12/08
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 3.35

WELL OWNER NUTP
INSTALLER G. Bell
INSTALLATION DATE 84/12/08
CASING ELEV. (m) 71.17
CASING LENGTH (m) 3.78
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 3.36
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

0.42 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	Pw (%)	Lw (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1T	ML	48.6	1118	20.2	26.6	SILT, very sandy, moist, dense, poorly graded, med. reddish brown, trace of clay Drilled to 3.35 m and vibrated piezometer into the hole

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TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Langley Bay
LOCATION ID: N5C
SITE COORDINATES:
N 2990
E 4010
GROUND ELEVATION (m) 70.75

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: McNeill
COMPLETION DATE: 84/12/08
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 2.13

WELL OWNER NUTP
INSTALLER G. Bell
INSTALLATION DATE 84/12/08
CASING ELEV. (m) 71.12
CASING LENGTH (m) 2.47
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 2.10
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

0.37 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	Pw (%)	Lw (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						Drilled to 2.13 m and vibrated piezometer down No sampling. Piezometer only installed.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: N6A
SITE COORDINATES:
N 1634
E 3905
GROUND ELEVATION (m) 99.87

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: Wiseman
COMPLETION DATE: 85/03/09
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 11.25

WELL OWNER NUTP
INSTALLER R. Boivin
INSTALLATION DATE 85/03/09 11:45
CASING ELEV. (m) 100.37
CASING LENGTH (m) 11.50
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Clay
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 11.0
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

T 0.50 m

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S0B		SM	23.0				SAND - very poorly graded, fine, reddish brown, silty, frozen.
	S1B	1	SM	21.5				
5	S2T	2	SM	40.4				End of frost at 2.0 m. No recovery at 2.3 m. Saturated.
10		3						No recovery at 3.0 m.
		4						SILT - very sandy, moist, stiff, non-plastic, reddish brown. Very little recovery at 4.6 m
15	S3B		ML	21.1				
		5	Tailings Interface					Lake Bottom at 5.3 m. CLAY - damp, very stiff, medium plastic, dark green, roots, coal specks. trace of sand. pp 150 to 240 kPa
	S4B	6	CI	35.9				

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main
LOCATION ID: N6A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft	DEPTH	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S5T		ML	20.7	1594	22.2	24.1	SILT, sandy reddish brown, in Shelby tube, probably slough (6.1 m).
			CI-CH					CLAY, moist, stiff, medium to highly plastic, grey. pp 100 kPa at 5.49 m
25		7						
	S6B	8	CI	43.1				
			CI					
30	S7T	9		36.0	1387	21.9	41.0	Auger refusal at 11.25 m. End of hole, pipe installed, possibly bedrock.
		10						9.5 m - Thermistor installed with lowest thermistor at 7.5m below top of pipe.
35		11						Thermistor string installed inside piezometer pipe.
40		12						
		13						
45		14						
		15						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main

TH - TEST HOLE / TP - TEST PIT TH

LOCATION ID N68

DRILLER / EXCAVATOR : Wiseman

SITE COORDINATES :

N 1634

E 3905

COMPLETION DATE : 85/03/09

TEST HOLE DIAMETER (m) : 0.056

TOTAL DEPTH (m) 5.20

GROUND ELEVATION (m) 99.90

WELL OWNER NUTP

FILTER PACK LENGTH (m)

INSTALLER R. Boivin

FORMATION OF COMPLETION : Tailings - Clay

INSTALLATION DATE 85/03/09 13:25

SEAL (END) DEPTH (m)

CASING ELEV. (m) 100.38

OPEN/SCREEN DEPTH (m) 5.15

CASING LENGTH (m) 5.63

OPEN / SCREEN LENGTH (m) 0.127

CASING DIAMETER (m) 0.035

OPEN / SCREEN AREA (m²) 0.0203

0.48 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						Frost to 1.7 m. No sampling. Piezometer only installed.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID : Gunnar Main

TH - TEST HOLE / TP - TEST PIT TH

LOCATION ID : N6C

DRILLER / EXCAVATOR : Wiseman

SITE COORDINATES :

N 1634

E 3905

COMPLETION DATE : 85/08/09

TEST HOLE DIAMETER (m) : 0.056

TOTAL DEPTH (m) 4.0

GROUND ELEVATION (m) 99.90

WELL OWNER NUTP

FILTER PACK LENGTH (m)

INSTALLER R. Boivin

FORMATION OF COMPLETION : Tailings

INSTALLATION DATE 85/03/09 14:06

SEAL (END) DEPTH (m)

CASING ELEV. (m) 100.23

OPEN/SCREEN DEPTH (m) 3.93

CASING LENGTH (m) 4.26

OPEN / SCREEN LENGTH (m) 0.127

CASING DIAMETER (m) 0.035

OPEN / SCREEN AREA (m²) 0.0203

0.33 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						No sampling. Piezometer only installed.

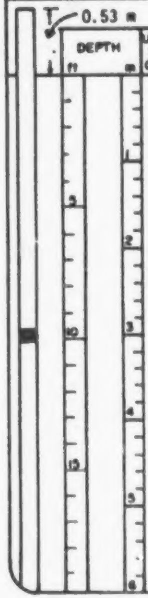
TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: N6D
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
COMPLETION DATE: 85/03/09
N 1635
TEST HOLE DIAMETER (m): 0.056
E 3904
TOTAL DEPTH (m) 3.0
GROUND ELEVATION (m) 99.89

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/09 14:50
SEAL (END) DEPTH (m)
CASING ELEV. (m) 100.42
OPEN/SCREEN DEPTH (m) 2.97
CASING LENGTH (m) 3.50
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY



UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					No drilling. Piezometer only installed.

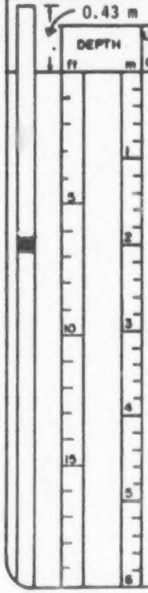
TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: N6E
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
COMPLETION DATE: 85/03/09
N 1635
TEST HOLE DIAMETER (m): 0.056
E 3903
TOTAL DEPTH (m) 2.0
GROUND ELEVATION (m) 99.88

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/09 15:20
SEAL (END) DEPTH (m)
CASING ELEV. (m) 100.31
OPEN/SCREEN DEPTH (m) 1.95
CASING LENGTH (m) 2.38
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY



UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					No drilling. Piezometer only installed.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main

TH - TEST HOLE / TP-TEST PIT: TH

LOCATION ID: GM1A

DRILLER / EXCAVATOR: R. Boivin

SITE COORDINATES:

N 1537

E 4107

COMPLETION DATE: 85/03

TEST HOLE DIAMETER (m):

TOTAL DEPTH (m)

GROUND ELEVATION (m) 104.35

WELL OWNER NUTP

INSTALLER R. Boivin

INSTALLATION DATE

CASING ELEV. (m)

CASING LENGTH (m)

CASING DIAMETER (m)

FILTER PACK LENGTH (m)

FORMATION OF COMPLETION:

SEAL (END) DEPTH (m)

OPEN / SCREEN DEPTH (m)

OPEN / SCREEN LENGTH (m)

OPEN / SCREEN AREA (m^2)

LITHOLOGICAL SUMMARY

DEPTH	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1	ML	27.2				Surface sample only retrieved. No drilling was done.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: GM2A

DRILLER / EXCAVATOR: Wiseman

SITE COORDINATES:

N 1426

E 3928

COMPLETION DATE: 85/03/29

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m) 8.40

GROUND ELEVATION (m) 104.10

Thermistor OWNER NUTP (8.75)

FILTER PACK LENGTH (m)

INSTALLER R. Boivin

FORMATION OF COMPLETION:

INSTALLATION DATE 85/03/29

SEAL (END) DEPTH (m)

CASING ELEV. (m)

8.75m THERM DEPTH (m) 5.27

CASING LENGTH (m)

OPEN / SCREEN LENGTH (m)

CASING DIAMETER (m)

OPEN / SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	SP	8.1				SAND - frozen to 1.1 m, damp below frost, medium dense, poorly graded, fine, reddish brown, frozen silt layers Vs and Nbn.
S2B	SP and ML layers	11.4				
S3B	SP and ML layers	14.7				Permafrost - layers from 1.1 to 3.0 m and depending on tube - to between 3.0 m and 3.8 m; solid ice and soil from approx. 3.8 m to 5.1 m - End at 5.1 m
S4T	SP	26.5	1519			
S5B	Nbe and V	24.7				Ice lenses
S6B	SM	23.6	1673			SAND - damp to moist, medium dense, poorly graded, fine, reddish brown, silty.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM2A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S7T	SM	18.1	1668			SAND - as above Nothing in sampler at 7.6 m, free water. Tailings Interface
S8B	CL	11.1				CLAY (gravelly) - damp, very stiff to hard, low plastic, dark greenish grey, very gravelly. Auger refusal at 8.4 m. 8.75 m string thermistor installed lowest at 5.27 m. Thermistor string installed in test hole and back filled with tailings.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM28

SITE COORDINATES

N 1427

E 3928

GROUND ELEVATION (m) 104.10

TH - TEST HOLE / TP - TEST PIT: TH

DRILLER / EXCAVATOR: Wiseman

COMPLETION DATE: 85/03/29

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m) 7.0

WELL OWNER NUTP

INSTALLER R. Boivin

INSTALLATION DATE 85/03/29 14:13

CASING ELEV. (m) 104.55*

CASING LENGTH (m) 7.42

CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)

FORMATION OF COMPLETION: Tailings

SEAL (END) DEPTH (m)

OPEN/SCREEN DEPTH (m) 6.97

OPEN / SCREEN LENGTH (m) 0.127

OPEN / SCREEN AREA (m^2) 0.0203

0.45 m

LITHOLOGICAL SUMMARY

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	SP	6.3				S1 - 0.0 to 0.2
S2B	SP	6.7				S2 - Above W.T.
S3B	SM Vx	23.8				S3 - Permafrost (3B) and SM split (3A) Piezometer would have been installed deeper but vibration cable on drilling rig broke. Pipe driven last 1.5 m by hand.

* Elevation calculated from ground elevation plus nine.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM28

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM2C
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
N 1425
E 3928
COMPLETION DATE: 85/03/29
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m): 3.85
GROUND ELEVATION (m) 104.10

WELL OWNER NUTP
INSTALLER R. Boivin
INSTALLATION DATE 85/03/29 16:23
CASING ELEV. (m) 104.45 *
CASING LENGTH (m) 4.17
CASING DIAMETER (m) 0.035
FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 3.82
OPEN / SCREEN LENGTH (m) 0.127
OPEN / SCREEN AREA (m²) 0.0203

T 0.35 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						Piezometer was to be installed lower but vibration cable on rig broke again. Attempted to go lower by just turning the bit but it would not penetrate the permafrost.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TP
LOCATION ID: GM2D
DRILLER / EXCAVATOR: G. Feasby
SITE COORDINATES:
N 1425
E 3928
COMPLETION DATE: 85/08
TEST HOLE DIAMETER (m):
TOTAL DEPTH (m) 1.3
GROUND ELEVATION (m) 104.10

WELL OWNER
INSTALLER
INSTALLATION DATE
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)
FILTER PACK LENGTH (m)
FORMATION OF COMPLETION:
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m)
OPEN / SCREEN LENGTH (m)
OPEN / SCREEN AREA (m²)

T

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
		4.9	1361			14°C
		4.7	1343			12.2°C
		14.3	1278			10.5°C
		7.0	1324			8.5°C

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 3

SITE ID: Gunnar Main
LOCATION ID: GM3A
SITE COORDINATES:
N 1214
E 3631
GROUND ELEVATION (m) 101.98

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR: Wiseman & McNeill
COMPLETION DATE: 85/03/28
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 19.8

OWNER NUTP (Thermistor)
INSTALLER R. Boivin
INSTALLATION DATE 85/03/28
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION:
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m)
OPEN/SCREEN LENGTH (m)
OPEN/SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH ft		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S1B		SP	7.9				SAND - frozen to 0.7 m, damp below frost, medium dense, poorly graded, fine, reddish brown.
		1						
5	S2B		SM	19.7				
		2						
10	S3B	3	ML	22.7	1695			Damp to moist.
	S4T	4	SP	24.1	1556			
15	S5B		SM	22.3				
		5						
	S6B	6	SM	18.6				

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 3

SITE ID: Gunnar Main
LOCATION ID: GM3A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S7T		SM	19.5	1697			Minimal recovery
		7						
25								Nothing in sampler at 7.6 m
		8						
	S8B	9	ML	24.6	1634			SILT - very sandy
30	S9T		SM	28.2	1509			SAND - as above
		10						
	S10 B		SM and		Tailings			SAND
35			OL	42.8	Interface			ORGANIC CLAY - damp, stiff, medium plastic, green, odour.
		11						
	B1B	12	Slough	21.6				Intended as biological sample, but another sample was used.
40	S11B		OL	79.8				ORGANIC CLAY - as above
	S12B		SM slough and OL and		CI bottom			CLAY - damp, stiff to very stiff, medium plastic, grey.
		13						
45								Drilled to 19.8 m, no bedrock.
		14						
		15						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 3 OF 3

SITE ID: Gunnar Main

LOCATION ID: GM3A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft.		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
50 55 60		16 17 18 19						
65	S13 B	20	CI	34.2				Thermistor string installed and backfilled with tailings. The string was 9.5 m long with the 9.5 m long thermistor at a depth of 4.4 m below ground surface.
70 75		21 22 23 24						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main	TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM38 - 0.45 m NE of A	DRILLER / EXCAVATOR: McNeill
SITE COORDINATES	COMPLETION DATE: 85/03/28
N 1214	TEST HOLE DIAMETER (m): 0.056
E 3631	TOTAL DEPTH (m): 10.03
GROUND ELEVATION (m): 101.98	
WELL OWNER: NUTP	FILTER PACK LENGTH (m):
INSTALLER: R. Boivin	FORMATION OF COMPLETION: Tailings - Clay
INSTALLATION DATE: 85/03/28 15:18	SEAL (END) DEPTH (m):
CASING ELEV. (m): 102.36 *	OPEN/SCREEN DEPTH (m): 9.90
CASING LENGTH (m): 10.28	OPEN/SCREEN LENGTH (m): 0.127
CASING DIAMETER (m): 0.035	OPEN/SCREEN AREA (m²): 0.0203

T 0.38 m

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
5 10 15	1 2 3 4 5 6						Piezometer vibrated last 6.0 m. No sampling. Piezometer only installed.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM38

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION SOIL TYPE AND COLOR
25 30 35 40 45	7 8 9 10 11 12 13 14 15						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM3C (0.46 m NE of B)
DRILLER / EXCAVATOR: McNeill
SITE COORDINATES:
COMPLETION DATE: 85/03/28
N 1215
TEST HOLE DIAMETER (m): 0.056
E 3632
TOTAL DEPTH (m) 4.6
GROUND ELEVATION (m) 101.98

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/28 15:45
SEAL (END) DEPTH (m)
CASING ELEV. (m) 102.50 *
OPEN/SCREEN DEPTH (m) 4.14
CASING LENGTH (m) 4.66
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

T 0.52 m

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
5 10 15	1 2 3 4 5 6						Piezometer vibrated last 2.0 m. No sampling. Piezometer only was installed.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM3D - (0.54 m NE of C)
DRILLER / EXCAVATOR: McNeill
SITE COORDINATES:
COMPLETION DATE: 85/03/28
N 1215
TEST HOLE DIAMETER (m): 0.056
E 3632
TOTAL DEPTH (m) 4.6
GROUND ELEVATION (m) 101.98

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/28 16:21
SEAL (END) DEPTH (m)
CASING ELEV. (m) 102.58 *
OPEN/SCREEN DEPTH (m) 4.28
CASING LENGTH (m) 4.88
OPEN / SCREEN LENGTH (m) 0.250
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0400

T 0.60 m

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
5 10 15	1 2 3 4 5 6						Piezometer vibrated last 2.0 m. No sampling. Piezometer only was installed.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: GM3E - 0.42 m NE of D

DRILLER / EXCAVATOR: McNeill

SITE COORDINATES:

N 1216

E 3633

COMPLETION DATE: 85/03/28

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m): 4.6

GROUND ELEVATION (m): 101.98

WELL OWNER: NUTP

INSTALLER: R. Boivin

INSTALLATION DATE: 85/03/28 17:07

CASING ELEV. (m): 102.43 *

CASING LENGTH (m): 4.86

CASING DIAMETER (m): 0.035

FILTER PACK LENGTH (m):

FORMATION OF COMPLETION: Tailings

SEAL (END) DEPTH (m):

OPEN / SCREEN DEPTH (m): 4.36

OPEN / SCREEN LENGTH (m): 0.375

OPEN / SCREEN AREA (m²): 0.0600

0.5 m

LITHOLOGICAL SUMMARY

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						Piezometer vibrated last 2.0 m. No sampling. Piezometer only was installed.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: GM4A

DRILLER / EXCAVATOR: Wiseman

SITE COORDINATES:

N 1632

E 3815

COMPLETION DATE: 85/03/12

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m): 4.8 m *

GROUND ELEVATION (m): 100.92

Thermistor OWNER: NUTP

INSTALLER: R. Boivin

INSTALLATION DATE: 85/03/12

CASING ELEV. (m):

CASING LENGTH (m):

CASING DIAMETER (m):

FILTER PACK LENGTH (m):

FORMATION OF COMPLETION:

SEAL (END) DEPTH (m):

OPEN / SCREEN DEPTH (m):

OPEN / SCREEN LENGTH (m):

OPEN / SCREEN AREA (m²):

LITHOLOGICAL SUMMARY

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	ML	36.5				SILT - frozen to 1.0 m, firm, low plastic, reddish brown, trace of sand, trace of clay,
S2T	SM	14.7	1245			Probably slough. 9.5 m thermistor string installed with 9.5 m thermistor at 4.2 m below ground surface. Backfilled with tailings.
S3B	SM	20.9				SAND - very moist, poorly graded, fine, dark reddish brown, silty.
S4B	SM	24.9	Tailings			Saturated.
S5B	CI	25.2	Interface			CLAY - moist, medium plastic, very stiff, grey-brown. Auger refusal at 4.8 m. 9.5 m String thermistor installed, lowest at 4.20 m. * (taped to outside of casing)

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM4B
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
COMPLETION DATE: 85/03/12
N 1631
TEST HOLE DIAMETER (m): 0.056
E 3815
TOTAL DEPTH (m) 4.6
GROUND ELEVATION (m) 100.98

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings - Clay
INSTALLATION DATE 85/03/12 16:16
SEAL (END) DEPTH (m)
CASING ELEV. (m) 101.38
OPEN/SCREEN DEPTH (m) 4.67
CASING LENGTH (m) 5.07
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY

T 0.4 m

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							No sampling. Piezometer only was installed.
5	1						
	2						Piezometer vibrated down.
10	3						
	4						
15	5						
	6						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TP
LOCATION ID: GM4C
DRILLER / EXCAVATOR: G. Feasby
SITE COORDINATES:
COMPLETION DATE: 85/08
N 1632
TEST HOLE DIAMETER (m):
E 3815
TOTAL DEPTH (m) 1.22
GROUND ELEVATION (m) 100.92

WELL OWNER
FILTER PACK LENGTH (m)
INSTALLER
FORMATION OF COMPLETION:
INSTALLATION DATE
SEAL (END) DEPTH (m)
CASING ELEV. (m)
OPEN/SCREEN DEPTH (m)
CASING LENGTH (m)
OPEN / SCREEN LENGTH (m)
CASING DIAMETER (m)
OPEN / SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

T

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B			14.7	1245			
5	1						11°C at 1.22 m
	2						
10	3						
	4						
15	5						
	6						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT TP
LOCATION ID: GM5A
DRILLER / EXCAVATOR: R. Boivin
SITE COORDINATES:
COMPLETION DATE 85/03
N 1519
TEST HOLE DIAMETER (m):
E 3819
TOTAL DEPTH (m)
GROUND ELEVATION (m) 101.46

WELL OWNER
FILTER PACK LENGTH (m)
INSTALLER
FORMATION OF COMPLETION:
INSTALLATION DATE
SEAL (END) DEPTH (m)
CASING ELEV. (m)
OPEN/SCREEN DEPTH (m)
CASING LENGTH (m)
OPEN / SCREEN LENGTH (m)
CASING DIAMETER (m)
OPEN / SCREEN AREA (m^2)

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1		SP	15.4				Surface sample only retrieved. No drilling was done.
5	1						
10	2						
15	3						
	4						
	5						
	6						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM6A On Knoll
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES
COMPLETION DATE: 85/03/14
N 1543
TEST HOLE DIAMETER (m): 0.056
E 3863
TOTAL DEPTH (m): 11.0
GROUND ELEVATION (m): 101.68

Thermistor OWNER: NUTP
FILTER PACK LENGTH (m):
INSTALLER: R. Boivin
FORMATION OF COMPLETION:
INSTALLATION DATE: 85/03/14
Lowest Therm. DEPTH (m): 4.15
CASING ELEV. (m): 101.93 *
OPEN/SCREEN DEPTH (m): 4.15
CASING LENGTH (m): 4.45
OPEN/SCREEN LENGTH (m): 0.127
CASING DIAMETER (m): 0.035
OPEN/SCREEN AREA (m²): 0.0203

0.3 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (Mg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	SM Vx	15.2				SAND - some frozen, some dry, visible ice crystals in frozen portion, poorly graded, fine, reddish brown and grey brown, reddish brown portions appear to be frozen, grey brown silty.
S2B	SM					Attempted tube at 1.8 m, no recovery.
S3B	SM	22.6				SAND - silty, frozen, very moist below frost, visible ice excess, crystals.
S8B	ICE & soil inclusions					3.6 m - ICE with soil inclusions.
S4B	ML	32.6				Less ice at 4.2 m again. SILT - saturated, low to non-plastic, reddish brown, sandy. Frost ends at 4.3 m. Nothing in core barrel at 4.6 m, nothing in core barrel at 6.0 m.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main
LOCATION ID: GM6A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (Mg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S5B	ML	33.5				SILT - saturated, low to non-plastic, reddish brown, sandy, greenish brown layers, trace roots, silty.
						Nothing in core barrel at 9.1 m.
S6B	CI					Minimal recovery at 10.7 m. CLAY - saturated, medium plastic, soft, light grey.
						Casing refusal at 11.0 m.
						8.75 m string thermistor installed, lowest at 4.15 m. Could not get pipe any lower even after cleaning out hole twice.
						Thermistor installed on outside of pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main

LOCATION ID: GM6B

SITE COORDINATES

N 1542

E 3863

GROUND ELEVATION (m) 101.68

TH - TEST HOLE / TP - TEST PIT TH

DRILLER / EXCAVATOR: Wiseman

COMPLETION DATE: 85/03/19

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m) 2.8

WELL OWNER NUTP

INSTALLER R. Boivin

INSTALLATION DATE 85/03/19

CASING ELEV. (m) 102.10 *

CASING LENGTH (m) 3.22

CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)

FORMATION OF COMPLETION: Tailings

SEAL (END) DEPTH (m)

OPEN/SCREEN DEPTH (m) 2.80

OPEN / SCREEN LENGTH (m) 0.127

OPEN / SCREEN AREA (m²) 0.0203

0.42 m

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							SAND - frozen, poorly graded, fine, reddish brown, silty.
							No samples retrieved. Piezometer only was installed.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main

LOCATION ID: GM6C

SITE COORDINATES:

N 1543

E 3863

GROUND ELEVATION (m) 101.68

TH - TEST HOLE / TP - TEST PIT: TP

DRILLER / EXCAVATOR: G. Feasby

COMPLETION DATE: 85/08

TEST HOLE DIAMETER (m):

TOTAL DEPTH (m) 1.37

WELL OWNER

INSTALLER

INSTALLATION DATE

CASING ELEV. (m)

CASING LENGTH (m)

CASING DIAMETER (m)

FILTER PACK LENGTH (m)

FORMATION OF COMPLETION:

SEAL (END) DEPTH (m)

OPEN/SCREEN DEPTH (m)

OPEN / SCREEN LENGTH (m)

OPEN / SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
			10.8	1197			11.2°C
			26.3	1085			
			16.3	1213			
			28.3	1235			7.8°C at 0.76 m
			28.0	1400			3.5°C at 1.07 m
							1.0°C at 1.22 m
							0.0°C at 1.37 m

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM7A
DRILLER / EXCAVATOR: Brinkman
SITE COORDINATES:
N 1370
E 3616
COMPLETION DATE: 84/11
TEST HOLE DIAMETER (m):
TOTAL DEPTH (m): Installation by Vibration
GROUND ELEVATION (m): 99.91

WELL OWNER: NUTP
INSTALLER: Brinkman/Blackport
INSTALLATION DATE: Nov. 84
CASING ELEV. (m): 100.61
CASING LENGTH (m): 2.67±
CASING DIAMETER (m): 0.035
FILTER PACK LENGTH (m):
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m):
OPEN/SCREEN DEPTH (m): 2.0±
OPEN/SCREEN LENGTH (m): 0.127
OPEN/SCREEN AREA (m²): 0.0203

T 0.67 m

LITHOLOGICAL SUMMARY

DEPTH ft		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S1		SM	37.1				SAND - moist, poorly graded, fine, reddish brown, silty. Surface sample only retrieved. No drilling was done. Piezometer installed by vibration.
		1						
5								
		2						
		3						
10								
		4						
15								
		5						
		6						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TP
LOCATION ID: GM8A
DRILLER / EXCAVATOR: R. Boivin
SITE COORDINATES:
N 1673
E 4034
COMPLETION DATE: 85/03
TEST HOLE DIAMETER (m):
TOTAL DEPTH (m):
GROUND ELEVATION (m): 101.36

WELL OWNER:
INSTALLER:
INSTALLATION DATE:
CASING ELEV. (m):
CASING LENGTH (m):
CASING DIAMETER (m):
FILTER PACK LENGTH (m):
FORMATION OF COMPLETION:
SEAL (END) DEPTH (m):
OPEN/SCREEN DEPTH (m):
OPEN/SCREEN LENGTH (m):
OPEN/SCREEN AREA (m²):

T

LITHOLOGICAL SUMMARY

DEPTH ft		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S1		SP	16.7				SAND - damp, poorly graded, fine, reddish brown, few fibres.
		1						
5								
		2						
		3						
10								
		4						
15								
		5						
		6						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM9A
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
COMPLETION DATE: 85/03/10
N 1658
TEST HOLE DIAMETER (m): 0.056
E 4107
TOTAL DEPTH (m) 4.65
GROUND ELEVATION (m) 101.44

WELL OWNER
FILTER PACK LENGTH (m)
INSTALLER
FORMATION OF COMPLETION:
INSTALLATION DATE
SEAL (END) DEPTH (m)
CASING ELEV. (m)
OPEN/SCREEN DEPTH (m)
CASING LENGTH (m)
OPEN / SCREEN LENGTH (m)
CASING DIAMETER (m)
OPEN / SCREEN AREA (m^2)

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						SAND - frozen to 1.8 m, poorly graded, fine, reddish brown, silty.
S1B	SM	21.3				Very wet, saturated portions below frost.
S2B	SM	27.5				Darker reddish brown at 3.0 m. Thin (< 5 mm) black lenses, loose - medium dense at 3.3 m. (hard drilling)
S3T	CL	19.6	1632	15.5	28.9	Clay - wet, low plastic, reddish brown. Ice lenses at 4.5 m (S4).
S4B						Auger refusal at 4.65 m.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM9B
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
COMPLETION DATE: 85/03/10
N 1658
TEST HOLE DIAMETER (m): 0.056
E 4107
TOTAL DEPTH (m) 4.1
GROUND ELEVATION (m) 101.44

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/10 10:59
SEAL (END) DEPTH (m)
CASING ELEV. (m) 101.81 *
OPEN/SCREEN DEPTH (m) 4.10
CASING LENGTH (m) 4.47
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m^2) 0.0203

LITHOLOGICAL SUMMARY

0.37 m

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						8.75 m Thermistor string installed with lowest thermistor at 5.2 m below top of pipe. **
						Thermistor string installed outside the piezometer pipe.
						No samples retrieved.
						** Fieldnote concerning lowest thermistor depth does not coincide with lowest depth of piezometer. Therefore assumed lowest thermistor at 4.2 m below top of pipe.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM9C
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
COMPLETION DATE: 85/03/10
N 1657
TEST HOLE DIAMETER (m): 0.056
E 4107
TOTAL DEPTH (m) 3.6 m
GROUND ELEVATION (m) 101.41

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/10 11:44
SEAL (END) DEPTH (m)
CASING ELEV. (m) 101.71
OPEN/SCREEN DEPTH (m) 3.54
CASING LENGTH (m) 3.84
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

T 0.3 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						No samples retrieved. Piezometer only was installed.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TP
LOCATION ID: GM10A
DRILLER / EXCAVATOR: R. Boivin
SITE COORDINATES:
COMPLETION DATE: 85/03
N 1171
TEST HOLE DIAMETER (m):
E 3988
TOTAL DEPTH (m)
GROUND ELEVATION (m) 109.69

WELL OWNER
FILTER PACK LENGTH (m)
INSTALLER
FORMATION OF COMPLETION:
INSTALLATION DATE
SEAL (END) DEPTH (m)
CASING ELEV. (m)
OPEN/SCREEN DEPTH (m)
CASING LENGTH (m)
OPEN / SCREEN LENGTH (m)
CASING DIAMETER (m)
OPEN / SCREEN AREA (m²)

T

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1	SP	10.6				SAND - dark, poorly graded, fine, reddish brown.
						Surface sample only was retrieved. No drilling was done.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TP
LOCATION ID: GM11A
DRILLER / EXCAVATOR: R. Boivin
SITE COORDINATES:
N 1071
E 3751
COMPLETION DATE: 85/03
TEST HOLE DIAMETER (m):
TOTAL DEPTH (m):
GROUND ELEVATION (m) 104.10

WELL OWNER
FILTER PACK LENGTH (m)
INSTALLER
FORMATION OF COMPLETION:
INSTALLATION DATE
SEAL (END) DEPTH (m)
CASING ELEV. (m)
OPEN/SCREEN DEPTH (m)
CASING LENGTH (m)
OPEN / SCREEN LENGTH (m)
CASING DIAMETER (m)
OPEN / SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1	SP	5.5				SAND - dark, poorly graded, fine to medium size, reddish brown.
						Surface sample only was retrieved. No drilling was done.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM12A
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
N 1197
E 3428
COMPLETION DATE: 85/08/20
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 3.6
GROUND ELEVATION (m) 100.95

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/08/20 15:35
SEAL (END) DEPTH (m)
CASING ELEV. (m) 101.22 *
OPEN/SCREEN DEPTH (m) 3.0
CASING LENGTH (m) 3.27
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY

0.27 m

DEPTH	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	CL	34.9				
						Frost to 0.7 m.
S2B	ML	53.1		24.8	32.3	SILT - saturated, very stiff, low plastic, reddish brown, trace of sand and clay, clayey at surface.
	ML	30.8	Tailings			Top - as above Bottom -
S3B	OL		Interface			ORGANIC CLAY - moist, soft, black roots, large tree root.
S4T	CL	17.8	1277			CLAY - moist, very stiff, low plastic, grey.
						Casing refusal at 3.6 m.

* Elevation calculated from ground elevation plus nine.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM128
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
COMPLETION DATE: 85/03/20
N 1197
TEST HOLE DIAMETER (m): 0.056
E 3428
TOTAL DEPTH (m) 1.8
GROUND ELEVATION (m) 100.95

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/20 16:00
SEAL (END) DEPTH (m)
CASING ELEV. (m) 101.35*
OPEN/SCREEN DEPTH (m) 1.77
CASING LENGTH (m) 2.17
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY

0.40 m

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
5 10 15	1 2 3 4 5 6						No drilling was done. Piezometer only was installed.

* Elevation calculated from ground elevation plus pipe

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM13A

SITE COORDINATES:

N 1444

E 3466

GROUND ELEVATION (m) 100.60

TH - TEST HOLE / TP - TEST PIT: TH

DRILLER / EXCAVATOR: Wiseman

COMPLETION DATE 85/03/19

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m) 9.8

WELL OWNER NUTP

INSTALLER R. Boivin

INSTALLATION DATE 85/03/19 16:45

CASING ELEV. (m) 100.92 *

CASING LENGTH (m) 7.18

CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)

FORMATION OF COMPLETION: Tailings - Clay

SEAL (END) DEPTH (m)

OPEN/SCREEN DEPTH (m) 6.86

OPEN/SCREEN LENGTH (m) 0.127

OPEN/SCREEN AREA (m²) 0.0203

0.32 m

LITHOLOGICAL SUMMARY

DEPTH ft. m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	ML	33.2				SILT - frozen, low plastic, very stiff, reddish brown, trace of fine sand. Frozen to 0.6 m.
S2B	ML	28.6	1031			SILT - saturated, low plastic, firm, reddish brown.
S3T	ML	28.6	1220	21.0	23.8	As above
S4B	ML	43.9				SILT - wet, low plastic, stiff, reddish brown, trace of grey.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM13A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft. m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S5T	CI	40.7	1308	22.3	31.2	Tailings clay interface at ~7 m if no clay in tube at 6.1 m.
						Tailings Interface
S7B	OL	63.2				ORGANIC CLAY - damp, low to med. plastic, stiff to very stiff, dark green, odour.
S6T	ML	50.3	1099	32.0	46.1	Possibly all slough in sample no. 6 tube.
S8B	OL-CI	34.3				ORGANIC CLAY - as above and CLAY mixed, possibly last 0.2-0.3 m. CI CLAY - damp, very stiff, medium plastic, grey, pp~140 kPa. Casing refusal at 9.8 m.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: GM13B

DRILLER / EXCAVATOR: Wiseman

SITE COORDINATES:

N 1444

E 3467

COMPLETION DATE: 85/03/20

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m) 3.2

GROUND ELEVATION (m) 100.60

WELL OWNER NUTP

FILTER PACK LENGTH (m)

INSTALLER R. Boivin

FORMATION OF COMPLETION: Tailings

INSTALLATION DATE 85/03/20 12:00

SEAL (END) DEPTH (m)

CASING ELEV. (m) 100.93*

OPEN/SCREEN DEPTH (m) 3.12

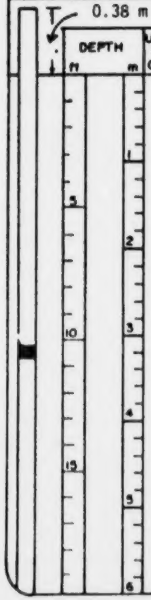
CASING LENGTH (m) 3.50

OPEN / SCREEN LENGTH (m) 0.127

CASING DIAMETER (m) 0.035

OPEN / SCREEN AREA (m^2) 0.0203

LITHOLOGICAL SUMMARY



DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						No samples were retrieved. Piezometer only was installed.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main	TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM17A	DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES	COMPLETION DATE: 85/03/12
N 1781	TEST HOLE DIAMETER (m): 0.056
E 3893	TOTAL DEPTH (m): 7.15
GROUND ELEVATION (m) 99.71	
WELL OWNER	FILTER PACK LENGTH (m)
INSTALLER	FORMATION OF COMPLETION:
INSTALLATION DATE	SEAL (END) DEPTH (m)
CASING ELEV. (m)	OPEN/SCREEN DEPTH (m)
CASING LENGTH (m)	OPEN/SCREEN LENGTH (m)
CASING DIAMETER (m)	OPEN/SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S6B	ML	42.6				SILT - frozen, non-plastic, reddish brown.
S1B	ML Vc	30.1				SILT - visible ice, reddish brown.
S2T	SM CL					TOP - SAND - wet, poorly graded, fine, reddish brown, silty, frost to 3.0 m. BOTTOM - CLAY - moist, very stiff, low plastic, grey.
S3B	CI	22.4				Thin black lenses at 4.8 m, medium plastic, permafrost, visible ice, crystals noted at 4.4 m.
S4T	CI-CH					TOP - CLAY - moist, possibly highly plastic, very stiff, light brown-grey.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM17A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft m	UNIFIED SOIL CLASS	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S4T	CI					BOTTOM - CLAY - damp, very stiff, medium plastic, greys, browns, dark greens to black, trace roots, possibly trace medium sand.
S5B	CI-CH	25.6				Sample 5 - CLAY - moist, as top of S4, light brown-grey.
						Refusal at 7.11 m (23'4").
						No piezometer installed.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
LOCATION ID: GM17B
SITE COORDINATES:
N 1781
E 3894
GROUND ELEVATION (m) 99.68

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: Wiseman
COMPLETION DATE: 85/03/12
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 3.4

WELL OWNER NUTP
INSTALLER R. Boivin
INSTALLATION DATE 85/03/12 9:23
CASING ELEV. (m) 100.02
CASING LENGTH (m) 3.64
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings - Clay
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 3.3
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY

0.34 m

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
5 10 15	1 2 3 4 5 6						No samples retrieved. Piezometer only installed.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
LOCATION ID: GM17C
SITE COORDINATES:
N 1780
E 3894
GROUND ELEVATION (m) 99.60

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR: Wiseman
COMPLETION DATE: 85/03/12
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 1.8

WELL OWNER NUTP
INSTALLER R. Boivin
INSTALLATION DATE 85/03/12 9:44
CASING ELEV. (m) 99.95
CASING LENGTH (m) 2.15
CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 1.8
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY

0.35 m

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
5 10 15	1 2 3 4 5 6						No samples retrieved. Piezometer only installed.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TP
LOCATION ID: GM18A
DRILLER / EXCAVATOR: R. Boivin
SITE COORDINATES:
COMPLETION DATE: 85/03
N: 1430
TEST HOLE DIAMETER (m):
E: 3673
TOTAL DEPTH (m):
GROUND ELEVATION (m): 100.34

WELL OWNER:
FILTER PACK LENGTH (m):
INSTALLER:
FORMATION OF COMPLETION:
INSTALLATION DATE:
SEAL (END) DEPTH (m):
CASING ELEV. (m):
OPEN/SCREEN DEPTH (m):
CASING LENGTH (m):
OPEN/SCREEN LENGTH (m):
CASING DIAMETER (m):
OPEN/SCREEN AREA (m²):

LITHOLOGICAL SUMMARY

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1	SM	26.1				SAND - moist, poorly graded, fine, reddish brown.
						Surface sample only retrieved.
						No drilling was done.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM19A
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
COMPLETION DATE: 85/03/12
N: 1563
TEST HOLE DIAMETER (m): 0.056
E: 3667
TOTAL DEPTH (m): 3.9
GROUND ELEVATION (m): 101.24

WELL OWNER:
FILTER PACK LENGTH (m):
INSTALLER:
FORMATION OF COMPLETION:
INSTALLATION DATE:
SEAL (END) DEPTH (m):
CASING ELEV. (m):
OPEN/SCREEN DEPTH (m):
CASING LENGTH (m):
OPEN/SCREEN LENGTH (m):
CASING DIAMETER (m):
OPEN/SCREEN AREA (m²):

LITHOLOGICAL SUMMARY

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S3B	ML	31.4				SILT - frozen to 1.0 m, low plastic, reddish brown, trace of clay.
S1B	SM-ML	28.7				SAND & SILT - moist, poorly graded, fine grained, dark reddish brown.
S2B	SM-ML	22.8				Attempted tube, no recovery. SAND & SILT - very moist.
						Casing refusal at 3.9 m.
						No clay noted.

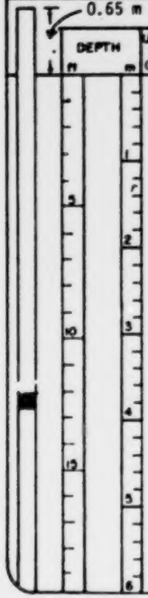
TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM19B
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
COMPLETION DATE: 85/03/12
N 1563
TEST HOLE DIAMETER (m): 0.056
E 3667
TOTAL DEPTH (m) 3.7
GROUND ELEVATION (m) 101.00

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/12 13:10
SEAL (END) DEPTH (m)
CASING ELEV. (m) 101.65
OPEN/SCREEN DEPTH (m) 3.70
CASING LENGTH (m) 4.35
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY



UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					No samples were retrieved. Piezometer only was installed.

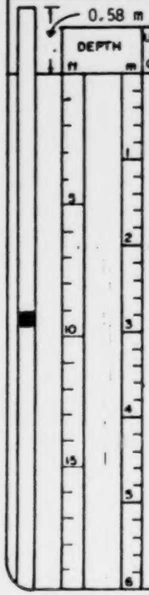
TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GM19C
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
COMPLETION DATE: 85/03/12
N 1563
TEST HOLE DIAMETER (m): 0.056
E 3668
TOTAL DEPTH (m) 2.5
GROUND ELEVATION (m) 101.41

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER Wiseman
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/12 13:53
SEAL (END) DEPTH (m)
CASING ELEV. (m) 101.99
OPEN/SCREEN DEPTH (m) 2.47
CASING LENGTH (m) 3.05
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY



UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					No samples were retrieved. Piezometer only was installed. Piezometer vibrated down.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main
LOCATION ID GM20
SITE COORDINATES (New Hole)
N 1550
E 3870
GROUND ELEVATION (m) 100.0 ±

TH - TEST HOLE / TP - TEST PIT TP
DRILLER / EXCAVATOR G. Feasby
COMPLETION DATE 85/08
TEST HOLE DIAMETER (m) :
TOTAL DEPTH (m) 1.43

WELL OWNER
INSTALLER
INSTALLATION DATE
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION :
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m)
OPEN / SCREEN LENGTH (m)
OPEN / SCREEN AREA (m^2)

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
		4.7	1327			14°C
		4.5	1384			12°C
		4.8	1409			11.1°C
						-7.0°C at 1.43 m

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main (Frog Pond)
LOCATION ID GM21
SITE COORDINATES
N 2082
E 4185
GROUND ELEVATION (m) 99.9 ±

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR BEAK
COMPLETION DATE 85/06/24
TEST HOLE DIAMETER (m) 0.05
TOTAL DEPTH (m) 1.00

WELL OWNER NUTP
INSTALLER D. Lush
INSTALLATION DATE 85/06/24
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)

FILTER PACK LENGTH (m) 0.10
FORMATION OF COMPLETION Silty Clay
SEAL (END) DEPTH (m) 1.00
OPEN/SCREEN DEPTH (m) 0.90
OPEN / SCREEN LENGTH (m) 0.10
OPEN / SCREEN AREA (m^2) 0.0094

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						0 - 5 cm organic soil
						5-75 cm reddish brown tailings
						75 - 85 cm organic soil
						85-100 silty clay
						50 mm hand auger piezometer installation.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main
TH - TEST HOLE / TP - TEST PIT TP
LOCATION ID GM22
DRILLER / EXCAVATOR BEAK
SITE COORDINATES
COMPLETION DATE 85/06/24
N 1270
TEST HOLE DIAMETER (m) 0.05
E 4136
TOTAL DEPTH (m) 0.90
GROUND ELEVATION (m) 104.5 ±
WELL OWNER NUTP
FILTER PACK LENGTH (m) 0.10
INSTALLER D. Lush
FORMATION OF COMPLETION Silty Clay Organic
INSTALLATION DATE 85/06/24
SEAL (END) DEPTH (m) 0.90
CASING ELEV (m)
OPEN/SCREEN DEPTH (m) 0.80
CASING LENGTH (m)
OPEN/SCREEN LENGTH (m) 0.10
CASING DIAMETER (m)
OPEN/SCREEN AREA (m²) 0.0094

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							0 - 5 cm organic silt and litter 5 - 85 cm reddish brown tailings 85 - 90 cm organic layer 90 cm silty clay 50 mm hand auger piezometer installation.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main
TH - TEST HOLE / TP - TEST PIT TH
LOCATION ID GM23
DRILLER / EXCAVATOR D. Lush
SITE COORDINATES
COMPLETION DATE 85/06/24
N 1646
TEST HOLE DIAMETER (m) 0.05
E 4200
TOTAL DEPTH (m) 1.00
GROUND ELEVATION (m) 99.5±
WELL OWNER NUTP
FILTER PACK LENGTH (m) 0.10
INSTALLER D. Lush
FORMATION OF COMPLETION Silty Clay
INSTALLATION DATE 85/06/24
SEAL (END) DEPTH (m) 1.00
CASING ELEV (m)
OPEN/SCREEN DEPTH (m) 0.90
CASING LENGTH (m)
OPEN/SCREEN LENGTH (m) 0.10
CASING DIAMETER (m)
OPEN/SCREEN AREA (m²) 0.0094

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							0 - 90 cm reddish brown tailings to 90 cm Organic from 90 - 95 cm 95 - 100 cm silty grey clay 50 mm hand auger piezometer installation.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
LOCATION ID: GM24
SITE COORDINATES:
N 1648
E 4366
GROUND ELEVATION (m) 98.5±
TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: D. Lush
COMPLETION DATE: 85/06/24
TEST HOLE DIAMETER (m): 0.05
TOTAL DEPTH (m) 1.10

WELL OWNER NUTP
INSTALLER D. Lush
INSTALLATION DATE 85/06/24
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)
FILTER PACK LENGTH (m) 0.10
FORMATION OF COMPLETION: Silty Reddish Brown Tailings
SEAL (END) DEPTH (m) 1.00
OPEN/SCREEN DEPTH (m) 0.90
OPEN/SCREEN LENGTH (m) 0.10
OPEN/SCREEN AREA (m²) 0.0094

LITHOLOGICAL SUMMARY

T	DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	5 10 15	1 2 3 4 5 6						Reddish brown tailings to depth of 1 m. Organic layer 10 cm silty clay below. 50 mm hand auger piezometer installation.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Main
LOCATION ID GM25
SITE COORDINATES
N 1670
E 3938
GROUND ELEVATION (m) 99.2±
TH - TEST HOLE / TP - TEST PIT TP
DRILLER / EXCAVATOR D. Lush
COMPLETION DATE 85/08/24
TEST HOLE DIAMETER (m):
TOTAL DEPTH (m)

WELL OWNER
INSTALLER
INSTALLATION DATE
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)
FILTER PACK LENGTH (m)
FORMATION OF COMPLETION:
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m)
OPEN/SCREEN LENGTH (m)
OPEN/SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

T	DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	5 10 15	1 2 3 4 5 6						Samples of sand and slime were retrieved for rare earth analysis. Surface samples only were retrieved. No drilling was done.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Central
LOCATION ID: GC5A
SITE COORDINATES:
N 2596
E 4400
GROUND ELEVATION (m) 83.11

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: Wiseman
COMPLETION DATE: 85/03/23
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 9.8

WELL OWNER
INSTALLER
INSTALLATION DATE
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION:
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m)
OPEN/SCREEN LENGTH (m)
OPEN/SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S9B	SM	28.8		Non-plastic		SAND - frozen, poorly graded, fine, reddish brown, silty. Frost to 1.5 m.
S1B S2T	ML	27.9				SILT - saturated, soft, non-plastic, reddish brown. Sample 2 - pushed tube 1.8 m to 2.4 m, no recovery; pushed to 3.6 m, minimal recovery.
S3B	ML	38.4				
						Tailings Interface
S4B	CI	37.5				CLAY - very moist, stiff, medium plastic, light grey.
S5T	CL	24.9	1255	18.0	25.8	CLAY - very moist, stiff, low plastic, light grey.
S6B	ML	43.3				

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Central
LOCATION ID: GC5A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S7T						No recovery.
S8B	CI	45.4				CLAY - very moist, very stiff, medium plastic, light brown-grey, very silty. Casing refusal at 9.8 m.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Central
LOCATION ID: GC58
SITE COORDINATES
N 2597
E 4400
GROUND ELEVATION (m) 83.11
TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR: Wiseman
COMPLETION DATE 85/03/23
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 4.0

WELL OWNER NUTP
INSTALLER R. Boivin
INSTALLATION DATE 85/03/23 17:00
CASING ELEV. (m) 83.35 *
CASING LENGTH (m) 3.34
CASING DIAMETER (m) 0.035
FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 3.10
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

0.24 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	ML					SILT - frozen, non-plastic, reddish brown, sandy.
S2B	ML - SM					Biological samples Frost to 1.3 m. Sandier at 0.6 m, less sand at 1.0 m again.
						Piezometer could not be pushed past 3.1 m.
S3T	ML Trace OL at bottom.					Tailings Interface

* Elevation calculated from ground elevation plus pipe

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Central
LOCATION ID: GC5C
SITE COORDINATES
N 2597
E 4400
GROUND ELEVATION (m) 83.11
TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR: Wiseman
COMPLETION DATE: 85/03/23
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 4.4

WELL OWNER NUTP
INSTALLER R. Boivin
INSTALLATION DATE 85/03/23 17:25
CASING ELEV. (m) 84.43 *
CASING LENGTH (m) 4.13
CASING DIAMETER (m) 0.035
FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Tailings - Clay
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 3.81
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

0.32 m

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						Biological samples.
S1B	ML					SILT - saturated, soft, non-plastic, reddish brown, trace fine sand.
S2T	ML CI	Tailings Interface				CLAY - moist, stiff, medium plastic, grey.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Central
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: GC6
DRILLER / EXCAVATOR: D. Lush
SITE COORDINATES
COMPLETION DATE: 85/06/23
N: 2560
TEST HOLE DIAMETER (m): 0.03
E: 4546
TOTAL DEPTH (m): 0.20
GROUND ELEVATION (m): 82.9 ±

WELL OWNER:
FILTER PACK LENGTH (m):
INSTALLER:
FORMATION OF COMPLETION:
INSTALLATION DATE:
SEAL (END) DEPTH (m):
CASING ELEV. (m):
OPEN/SCREEN DEPTH (m):
CASING LENGTH (m):
OPEN/SCREEN LENGTH (m):
CASING DIAMETER (m):
OPEN/SCREEN AREA (m²):

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION SOIL TYPE AND COLOR
5 10 15	1 2 3 4 5 6						0 - 2 cm white crystaline tailings material 2 - 20 cm crystaline material is less with depth and sandy reddish brown tailings Surface sample only was retrieved. No drilling was done.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Central
TH - TEST HOLE / TP - TEST PIT: TP
LOCATION ID: GC7
DRILLER / EXCAVATOR: D. Lush
SITE COORDINATES
COMPLETION DATE: 85/06/23
N: 2630
TEST HOLE DIAMETER (m):
E: 4405
TOTAL DEPTH (m): 0.01 - Surface Sample
GROUND ELEVATION (m): 82.1 ±

WELL OWNER:
FILTER PACK LENGTH (m):
INSTALLER:
FORMATION OF COMPLETION:
INSTALLATION DATE:
SEAL (END) DEPTH (m):
CASING ELEV. (m):
OPEN/SCREEN DEPTH (m):
CASING LENGTH (m):
OPEN/SCREEN LENGTH (m):
CASING DIAMETER (m):
OPEN/SCREEN AREA (m²):

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION SOIL TYPE AND COLOR
5 10 15	1 2 3 4 5 6						White crust on tailings Surface sample only was retrieved. No drilling was done.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Gunnar Central
LOCATION ID GC8
SITE COORDINATES
N 2628
E 4340
GROUND ELEVATION (m) 82.2 ±

TH - TEST HOLE / TP - TEST PIT TP
DRILLER / EXCAVATOR D. Lush
COMPLETION DATE : 85/06/23
TEST HOLE DIAMETER (m) :
TOTAL DEPTH (m) 0.01 Surface Sample

WELL OWNER
INSTALLER
INSTALLATION DATE
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION :
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m)
OPEN/SCREEN LENGTH (m)
OPEN/SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

T	DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							White crust on tailings.
							Surface sample only was retrieved.
							No drilling was done.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 3

SITE ID : Langley Bay
LOCATION ID : LB2A
SITE COORDINATES :
N 2813
E 3877
GROUND ELEVATION (m) 69.89

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR : Wiseman
COMPLETION DATE : 85/03/24
TEST HOLE DIAMETER (m) : 0.056
TOTAL DEPTH (m) 19.8

WELL OWNER
INSTALLER
INSTALLATION DATE
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION :
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m)
OPEN/SCREEN LENGTH (m)
OPEN/SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

T	DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S1B	ML	28.6				SILT - frozen, soft, low plastic, dark reddish brown, SAND at surface.
							Frost to 0.7 m.
	S2B	ML	48.8				SILT - saturated, soft, non-plastic, reddish brown, little fine sand.
	S3T	CI	39.7	1053	24.0	40.0	CLAY, Silt at 1.9 m, med. plastic See Note LB2C
	S4B	ML	45.3				
	S5T	ML TOP	39.0	1404			Tailings Interface
		OL BOTTOM					ORGANIC CLAY - moist, soft, pp 0.3 TSF, High plastic, green, odour, small roots.
	S6B	OH-MH	82.8				
	S7T	OH-MH	86.3	1296	40.1	60.7	Slightly lighter green pp-0 kPa
	S8B	CI	62.0				CLAY - moist, medium plastic, very stiff, grey.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 3

SITE ID: Langley Bay
LOCATION ID: LB2A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
S9B	CI	30.2				CLAY - as above
S10 B	CI	33.2				ORGANIC CLAY - as above, lt. brown-grey.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 3 OF 3

SITE ID: Langley Bay
LOCATION ID: LB2A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
S11 B	CI	40.4		22.5	36.2	ORGANIC CLAY - as above. med. plastic End of Hole at 19.8 m (65').

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Langley Bay
LOCATION ID: LB2B
SITE COORDINATES
N 2813
E 3877
GROUND ELEVATION (m) 69.89

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: Wiseman
COMPLETION DATE: 85/03/24
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 3.6

WELL OWNER: NUTP
INSTALLER: R. Boivin
INSTALLATION DATE: 85/03/24 12:55
CASING ELEV. (m): 70.24 *
CASING LENGTH (m): 3.94
CASING DIAMETER (m): 0.035

FILTER PACK LENGTH (m):
FORMATION OF COMPLETION: Tailings - Clay
SEAL (END) DEPTH (m):
OPEN/SCREEN DEPTH (m): 3.59
OPEN/SCREEN LENGTH (m): 0.127
OPEN/SCREEN AREA (m²): 0.0203

LITHOLOGICAL SUMMARY

0.35 m

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	ML					Biological Samples
S2B	ML					SILT - frozen, non-plastic, reddish brown.
S3T	No recovery.					Piezometer vibrated last 0.6 m due to slough.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Langley Bay
LOCATION ID: LB2C
SITE COORDINATES
N 2813
E 3878
GROUND ELEVATION (m) 69.89

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: Wiseman
COMPLETION DATE: 85/03/24
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 4.2

WELL OWNER: NUTP
INSTALLER: R. Boivin
INSTALLATION DATE: 85/03/24 13:17
CASING ELEV. (m): 70.29*
CASING LENGTH (m): 3.78
CASING DIAMETER (m): 0.035

FILTER PACK LENGTH (m):
FORMATION OF COMPLETION: Tailings
SEAL (END) DEPTH (m):
OPEN/SCREEN DEPTH (m): 3.38
OPEN/SCREEN LENGTH (m): 0.127
OPEN/SCREEN AREA (m²): 0.0203

LITHOLOGICAL SUMMARY

0.40 m

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						Biological Samples
S1B	ML Nb					Note: Frozen samples noted at 3.1 m. Driller thought aoprox. 0.3 m of hard drilling due to frost.
S2T	ML UL	Top Botton		Tailinns Interface		

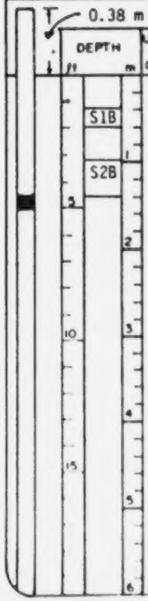
* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID:	Langley Bay	TH - TEST HOLE / TP - TEST PIT	TH
LOCATION ID.	LB3A	DRILLER / EXCAVATOR	Wiseman
SITE COORDINATES:		COMPLETION DATE	85/03/25
N	3192	TEST HOLE DIAMETER (m):	0.056
E	4154	TOTAL DEPTH (m)	1.4
GROUND ELEVATION (m)	69.84		
WELL OWNER	NUTP	FILTER PACK LENGTH (m)	
INSTALLER	R. Boivin	FORMATION OF COMPLETION	Tailings
INSTALLATION DATE	85/03/25 12:43	SEAL (END) DEPTH (m)	
CASING ELEV. (m)	70.22 *	OPEN / SCREEN DEPTH (m)	1.40
CASING LENGTH (m)	1.78	OPEN / SCREEN LENGTH (m)	0.127
CASING DIAMETER (m)	0.035	OPEN / SCREEN AREA (m²)	0.0203

LITHOLOGICAL SUMMARY



DEPTH	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION SOIL TYPE AND COLOR
						ICE for approx. 0.2 m.
S1B	SM	31.4				SAND - frozen, poorly graded, fine, reddish brown.
S2B	SM	29.9				Casing refusal at 1.4 m.

* Elevation calculated from ground elevation plus pipe

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID Langley Bay

LOCATION ID LB3B

SITE COORDINATES

N 3192

E 4154

GROUND ELEVATION (m) 69.84

TH - TEST HOLE / TP - TEST PIT TH

DRILLER / EXCAVATOR Wiseman

COMPLETION DATE 85/03/25

TEST HOLE DIAMETER (m) : 0.056

TOTAL DEPTH (m) 13.1

WELL OWNER

INSTALLER

INSTALLATION DATE

CASING ELEV. (m)

CASING LENGTH (m)

CASING DIAMETER (m)

FILTER PACK LENGTH (m)

FORMATION OF COMPLETION

SEAL (END) DEPTH (m)

OPEN / SCREEN DEPTH (m)

OPEN / SCREEN LENGTH (m)

OPEN / SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						Frost and Ice to ∽1.9 m.
S1B	SM-ML	27.4				SAND & SILT - wet, poorly graded, fine, reddish brown.
						Tailings Interface (Assumed)
S2B S3B	OL OL	68.9 72.9		32.4	48.4	ORGANIC CLAY - moist, firm, pp 60 kPa, medium plastic, green darker green at 4.3 m.
S4B	CI	31.1				CLAY - moist, stiff, 80 kPa, medium plastic, grey.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Langley Bay

LOCATION ID: LB3B

LITHOLOGICAL SUMMARY (CONTINUED)

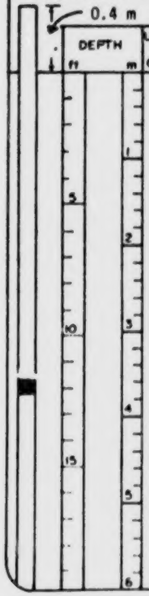
DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S5B	CI	51.8				CLAY - moist, stiff, medium plastic, light brownish grey.
S6B	CI	45.5				CLAY - as above.
						Casing refusal at 13.1 m.
						No tube samples as no tubes available.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID:	Langley Bay	TH - TEST HOLE / TP - TEST PIT:	TH
LOCATION ID:	LB3C	DRILLER / EXCAVATOR:	Wiseman
SITE COORDINATES:		COMPLETION DATE	85/03/25
N	3191	TEST HOLE DIAMETER (m):	0.056
E	4154	TOTAL DEPTH (m)	3.7
GROUND ELEVATION (m)	69.84		
WELL OWNER	NUTP	FILTER PACK LENGTH (m)	
INSTALLER	R. Boivin	FORMATION OF COMPLETION:	Tailings - Clay
INSTALLATION DATE	85/03/25 14:12	SEAL (END) DEPTH (m)	
CASING ELEV. (m)	70.24 *	OPEN/SCREEN DEPTH (m)	3.6
CASING LENGTH (m)	4.0	OPEN / SCREEN LENGTH (m)	0.127
CASING DIAMETER (m)	0.035	OPEN / SCREEN AREA (m^2)	0.0203

LITHOLOGICAL SUMMARY



UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					No samples were retrieved. Piezometer only was installed.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID Langley Bay
LOCATION ID: LB7A
SITE COORDINATES
N 3119
E 4105
GROUND ELEVATION (m) 69.89

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR Wiseman
COMPLETION DATE 85/03/25
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 11.3

WELL OWNER
INSTALLER
INSTALLATION DATE
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)

FILTER PACK LENGTH (m)
FORMATION OF COMPLETION:
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m)
OPEN/SCREEN LENGTH (m)
OPEN/SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	ML-SM	33.4				SILT - frozen to 0.35 m, saturated, firm, non-plastic, reddish brown, sandy.
S2B	ML-SM	35.6		NP	NP	
S3T	ML	29.2	1375			Tailings Interface
	OL					pp 120 kPa
S4B	OH	47.3				ORGANIC SILT - damp, stiff, highplastic, little more plastic with depth, grey-green.
S5T	OH	57.6	1342	36.1	54.3	pp 120 kPa at 2.4 m. 140 kPa at 2.7 m. 30 kPa at 3.4 m.
S6B	CI	29.7				CLAY - moist, medium plastic, firm, grey.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Langley Bay
LOCATION ID: LB7A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S7B	CI	45.7				CLAY - moist, firm, medium plastic, light brownish grey.
S8B	CL	39.9		20.0	25.0	CLAY - silty, moist, low plastic. Auger refusal at 11.3 m.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Langley Bay
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: LB7B
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
N 3119
E 4105
COMPLETION DATE: 85/03/25
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 4.2
GROUND ELEVATION (m) 69.89

WELL OWNER NUTP
INSTALLER R. Boivin
INSTALLATION DATE 85/03/25 10:14
CASING ELEV. (m) 70.24*
CASING LENGTH (m) 4.45
CASING DIAMETER (m) 0.035
FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Clay
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 4.10
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203

T
0.35 m
ft
m
1
2
3
4
5
6
5
10
15

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						No samples were retrieved. Piezometer only was installed.

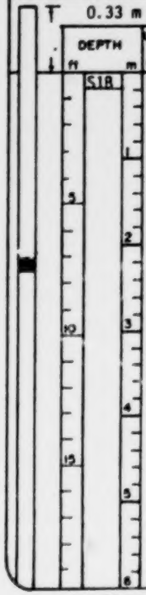
* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Langley Bay
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: LB7C
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
N 3119
E 4106
COMPLETION DATE: 85/03/25
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 2.2
GROUND ELEVATION (m) 69.89

WELL OWNER NUTP
INSTALLER R. Boivin
INSTALLATION DATE 85/03/25 10:24
CASING ELEV. (m) 70.22*
CASING LENGTH (m) 2.46
CASING DIAMETER (m) 0.035
FILTER PACK LENGTH (m)
FORMATION OF COMPLETION: Clay
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 2.13
OPEN/SCREEN LENGTH (m) 0.127
OPEN/SCREEN AREA (m²) 0.0203



LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						No samples were retrieved. Piezometer only was installed.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Waste Rock
TH - TEST HOLE / TP - TEST PIT TH
LOCATION ID WR1
DRILLER / EXCAVATOR D. Lush
SITE COORDINATES
N 465
COMPLETION DATE 84/06/23
TEST HOLE DIAMETER (m) : 0.03
E 4555
TOTAL DEPTH (m) 1.00
GROUND ELEVATION (m) 69.0 ±

WELL OWNER NUTP
FILTER PACK LENGTH (m) 0.10
INSTALLER D. Lush
FORMATION OF COMPLETION : Silty Clav
INSTALLATION DATE 84/06/23
SEAL (END) DEPTH (m)
CASING ELEV (m)
OPEN/SCREEN DEPTH (m) 0.90
CASING LENGTH (m)
OPEN / SCREEN LENGTH (m) 0.10
CASING DIAMETER (m)
OPEN / SCREEN AREA (m²) 0.0094

LITHOLOGICAL SUMMARY

T	DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	5 10 15	1 2 3 4 5 6						0 - 2 cm organic soil 2 - 100 cm varved silty clay some iron staining on varves.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID Waste Rock
TH - TEST HOLE / TP - TEST PIT TH
LOCATION ID WR2
DRILLER / EXCAVATOR D. Lush
SITE COORDINATES
COMPLETION DATE 85/06/23
N 465
TEST HOLE DIAMETER (m) 0.03
E 4727
TOTAL DEPTH (m) 1.00
GROUND ELEVATION (m) 72.8 ±

WELL OWNER NUTP
FILTER PACK LENGTH (m) 0.10
INSTALLER D. Lush
FORMATION OF COMPLETION : Silty Clay
INSTALLATION DATE 85/06/23
SEAL (END) DEPTH (m)
CASING ELEV. (m)
OPEN/SCREEN DEPTH (m) 0.90
CASING LENGTH (m)
OPEN / SCREEN LENGTH (m) 0.10
CASING DIAMETER (m)
OPEN / SCREEN AREA (m²) 0.0094

LITHOLOGICAL SUMMARY

T	DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	5 10 15	1 2 3 4 5 6		19.2				0 - 2 cm organic soil. 2 - 100 cm silty varved clay

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Waste Rock
LOCATION ID: WR3
SITE COORDINATES
N 622
E 4790
GROUND ELEVATION (m) 72.5 ±

TH - TEST HOLE / TP - TEST PIT: TH
DRILLER / EXCAVATOR: D. Lush
COMPLETION DATE: 85/06/23
TEST HOLE DIAMETER (m): 0.03
TOTAL DEPTH (m) 1.0

WELL OWNER NUTP
INSTALLER D. Lush
INSTALLATION DATE 85/06/23
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)

FILTER PACK LENGTH (m) 0.10
FORMATION OF COMPLETION: Silty clay
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 0.90
OPEN / SCREEN LENGTH (m) 0.10
OPEN / SCREEN AREA (m²) 0.0094

LITHOLOGICAL SUMMARY

T	DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	5 10 15	1 2 3 4 5 6		28.2				0 - 3 cm organic soil. 3 - 100 cm silty varved clay.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Waste Rock
LOCATION ID: WR4
SITE COORDINATES
N 718
E 4750
GROUND ELEVATION (m) 73.8 ±

TH - TEST HOLE / TP - TEST PIT TH
DRILLER / EXCAVATOR D. Lush
COMPLETION DATE 85/06/23
TEST HOLE DIAMETER (m): 0.03
TOTAL DEPTH (m) 0.90

WELL OWNER NUTP
INSTALLER D. Lush
INSTALLATION DATE 85/06/23
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)

FILTER PACK LENGTH (m) 0.10
FORMATION OF COMPLETION Hard Packed Clay
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 0.80
OPEN / SCREEN LENGTH (m) 0.10
OPEN / SCREEN AREA (m²) 0.0094

LITHOLOGICAL SUMMARY

T	DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	5 10 15	1 2 3 4 5 6		14.6				Silty hard packed clay, some pinkish color - 0 - 90 cm.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

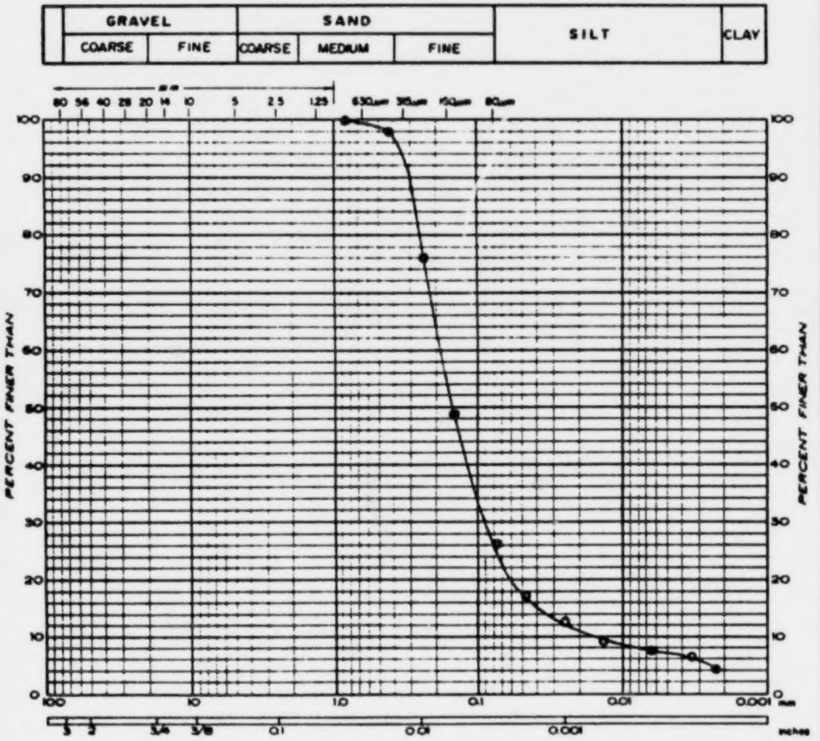
SITE ID	Waste Rock	TH - TEST HOLE / TP - TEST PIT	TH
LOCATION ID	WR5	DRILLER / EXCAVATOR	D. Lush
SITE COORDINATES		COMPLETION DATE	85/06/23
N	750	TEST HOLE DIAMETER (m)	0.03
E	5030	TOTAL DEPTH (m)	1.10
GROUND ELEVATION (m)	72 ±		
WELL OWNER	NUTP	FILTER PACK LENGTH (m)	0.10
INSTALLER	D. Lush	FORMATION OF COMPLETION	Silty Clay
INSTALLATION DATE	85/06/23	SEAL (END) DEPTH (m)	
CASING ELEV. (m)		OPEN / SCREEN DEPTH (m)	1.00
CASING LENGTH (m)		OPEN / SCREEN LENGTH (m)	0.10
CASING DIAMETER (m)		OPEN / SCREEN AREA (m²)	0.0094

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION SOIL TYPE AND COLOR
			25.4				Very tight silty clay, some fracturing along what may be varves. Very thin 2 cm top-soil on surface.

4.4.3 Grain Size Distribution Curves

The following grain size distribution curves include dupicate results as indicated on the sheets. A limited number of dry sieve analysis were performed to confirm the results (i.e. minus No. 200 and No. 400) also as noted on the sheets.



D_{60} = 0.19 mm D_{30}: 0.09 m D_{10}: 0.015 mm

TAILINGS

REMARKS SAND - silty, moist, loose, fine, poorly graded, (uniform) medium reddish brown

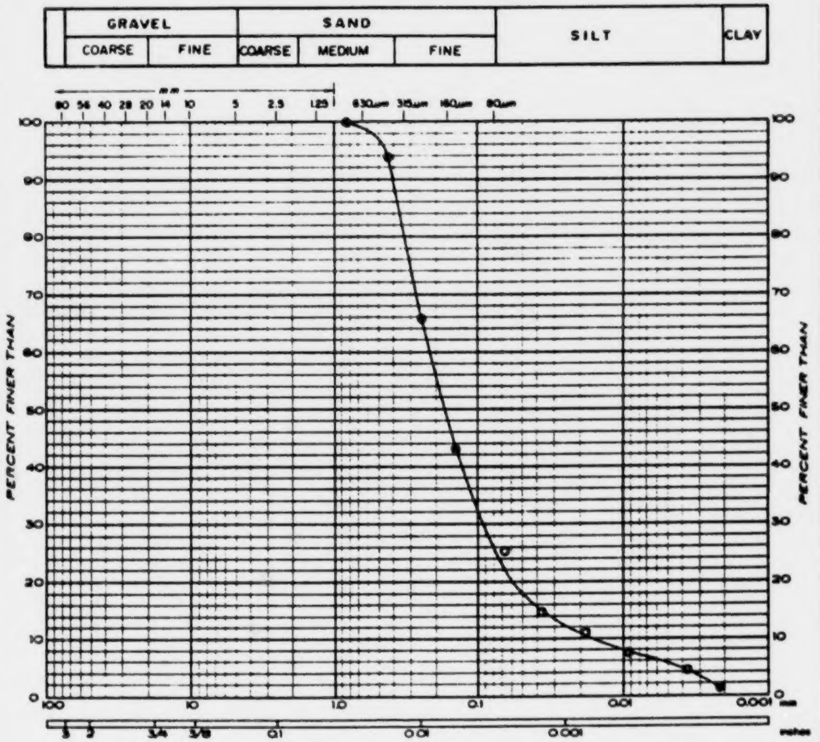
Geotechnical Consultants Ltd.

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N/A Depth 3.7 to 4.3m
Sample No. 31

DRAWING NO



D_{60}: 0.22 mm D_{30}: 0.091 mm D_{10}: 0.017 mm

TAILINGS

REMARKS SAND - moist, medium dense, poorly graded (uniform) medium reddish brown, some silt.

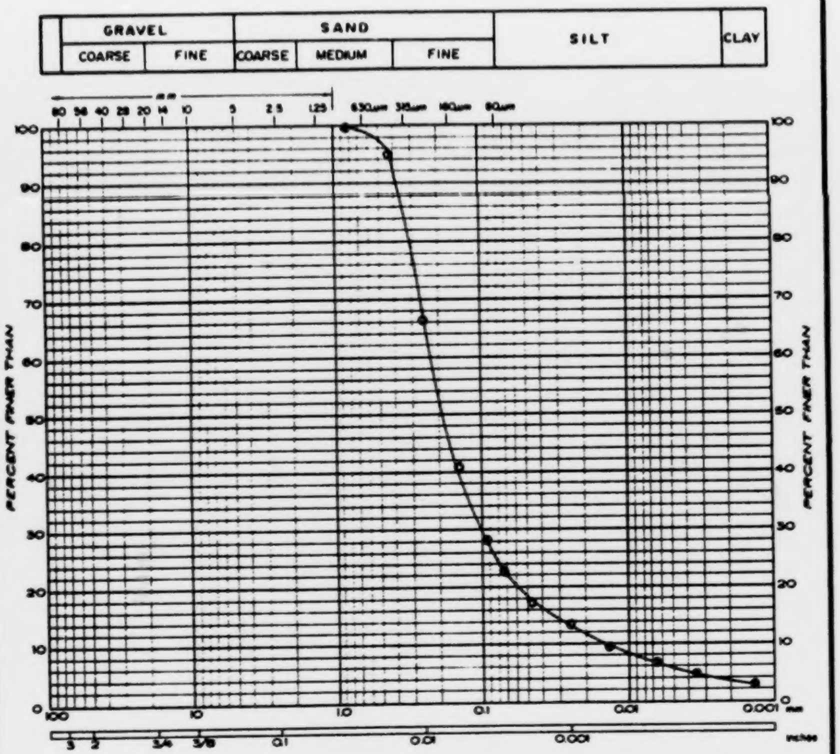
Geotechnical Consultants Ltd.

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N/C Depth 0 to 0.6m
Sample No. 31

DRAWING NO



D_{60} = 0.22 mm D_{30} = 0.1 mm D_{10} = 0.014 mm

TAILINGS

REMARKS SAND - moist, medium dense, poorly graded (uniform), medium reddish brown, some silt

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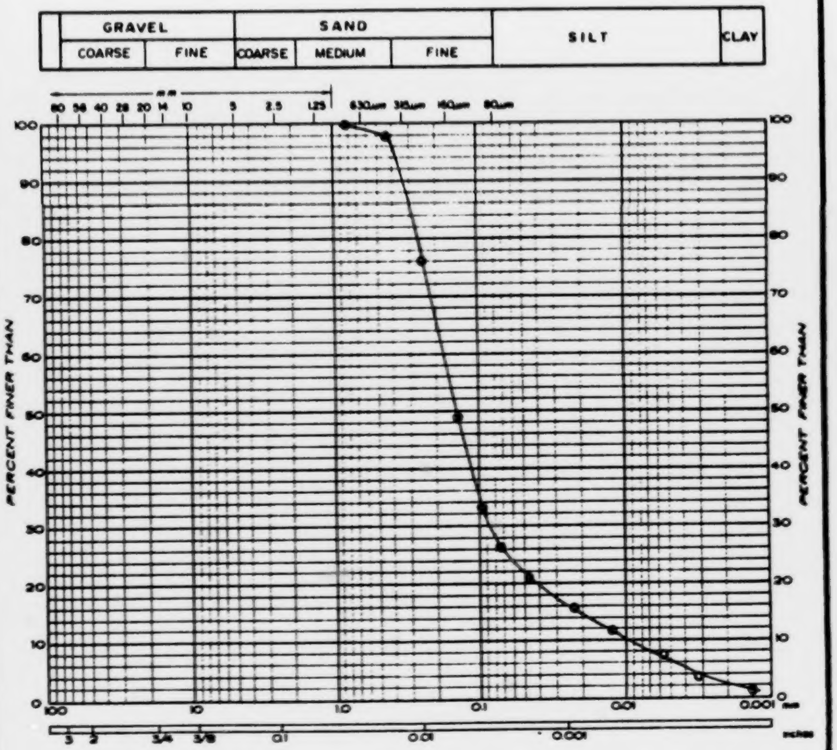
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N/C Depth 1.5 to 2.1m
Sample No 52

DRAWING NO.



D_{60} = 0.18 mm D_{30} = 0.088 mm D_{10} = 0.01 mm

TAILINGS

REMARKS SAND: moist, medium dense, poorly graded (uniform), medium reddish brown, silty

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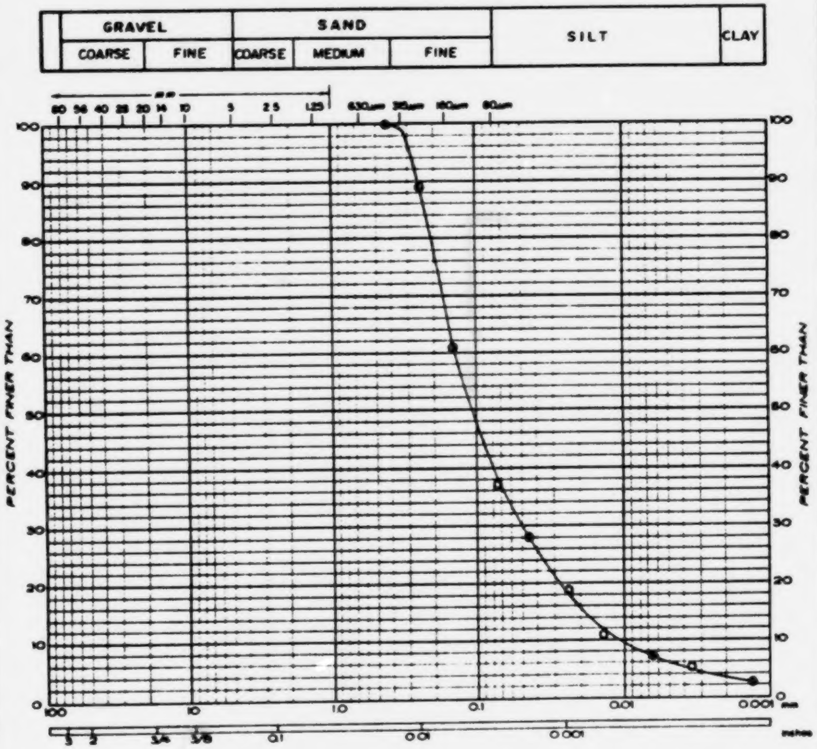
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N/C Depth 3 to 3.7m
Sample No 53

DRAWING NO



TAILINGS

D_{60}: 0.13 mm D_{30}: 0.05mm D_{10}: 0.011mm

REMARKS SAND silty, moist, medium dense, fine, poorly graded, medium reddish brown

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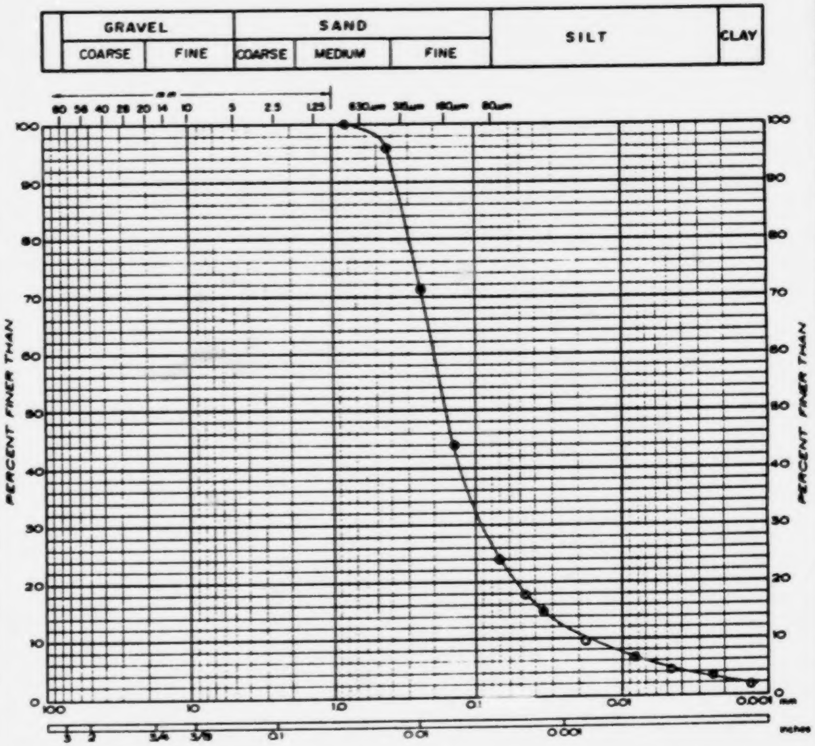
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N/C Depth 6.1 to 6.7m
Sample No. 35

DRAWING NO.



TAILINGS

D_{60}: 0.2mm D_{30}: 0.092 D_{10}: 0.018mm

REMARKS SAND silty, moist, medium dense, fine, poorly graded, medium reddish brown

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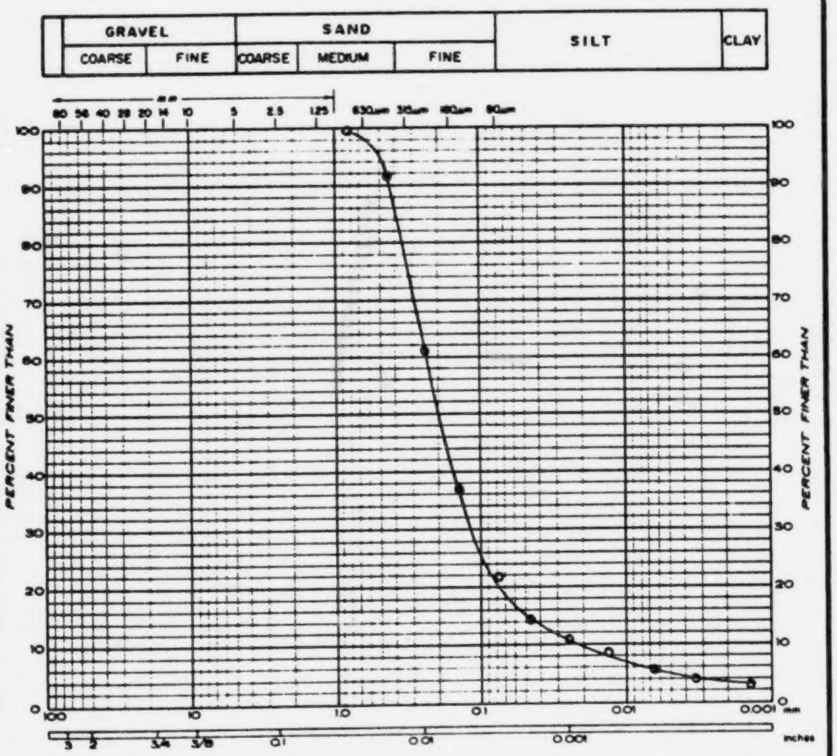
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N/C Depth 7.6 to 8.2m
Sample No. 36

DRAWING NO.



TAILINGS

D_{60}: 0.24mm D_{30}: 0.078mm D_{10}: 0.021mm

REMARKS SAND – silty, wet, medium dense, fine, poorly graded, medium reddish brown

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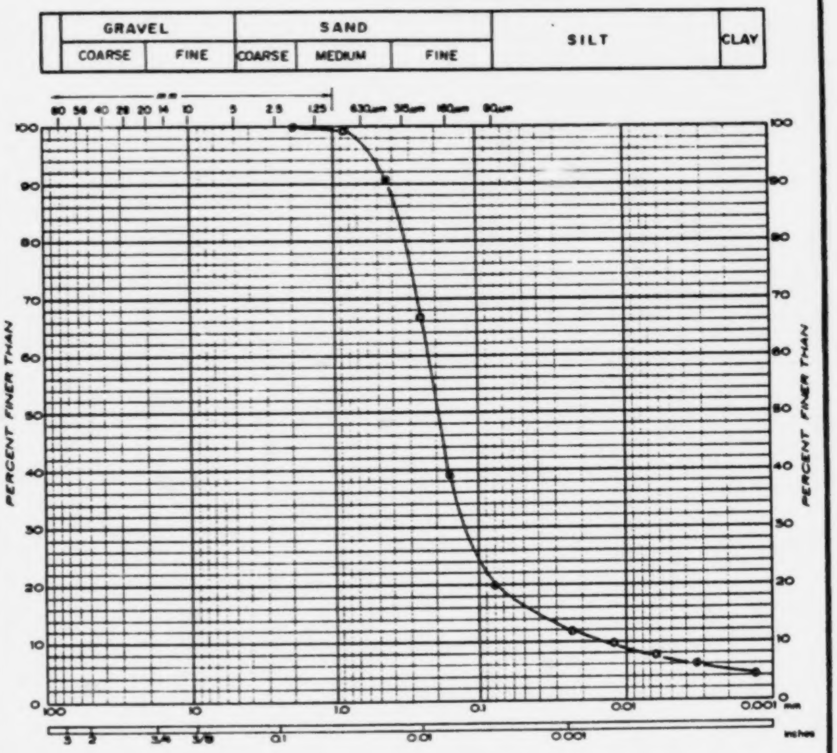
GRAIN SIZE DISTRIBUTION

Test Hole No. N/C Depth 9.1m to 9.7 m
Sample No. 57

DRAWING NO.



TAILINGS

D_{60}: 0.11mm D_{30}: 0.12mm D_{10}: 0.014mm

REMARKS SAND - silty, moist, medium dense, poorly graded, medium reddish brown (duplicate sample)

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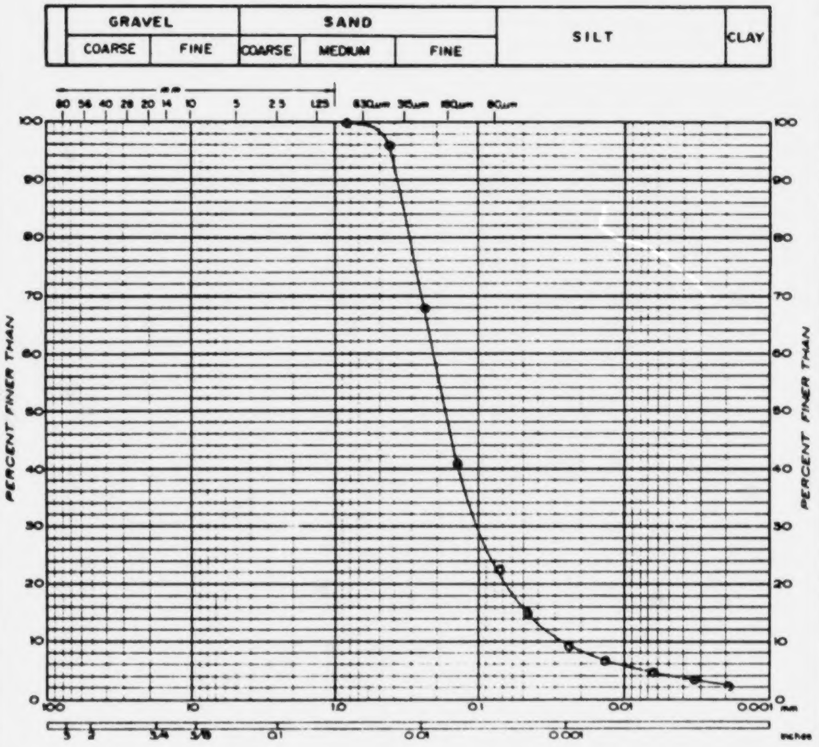
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N/C Depth 9.1 m to 9.7m
Sample No. 57B

DRAWING NO.



D_{60}: 0.21 mm D_{30}: 0.1 mm D_{10} : 0.026 mm

TAILINGS

REMARKS SAND- silty, wet, medium dense, fine, poorly graded, medium reddish brown

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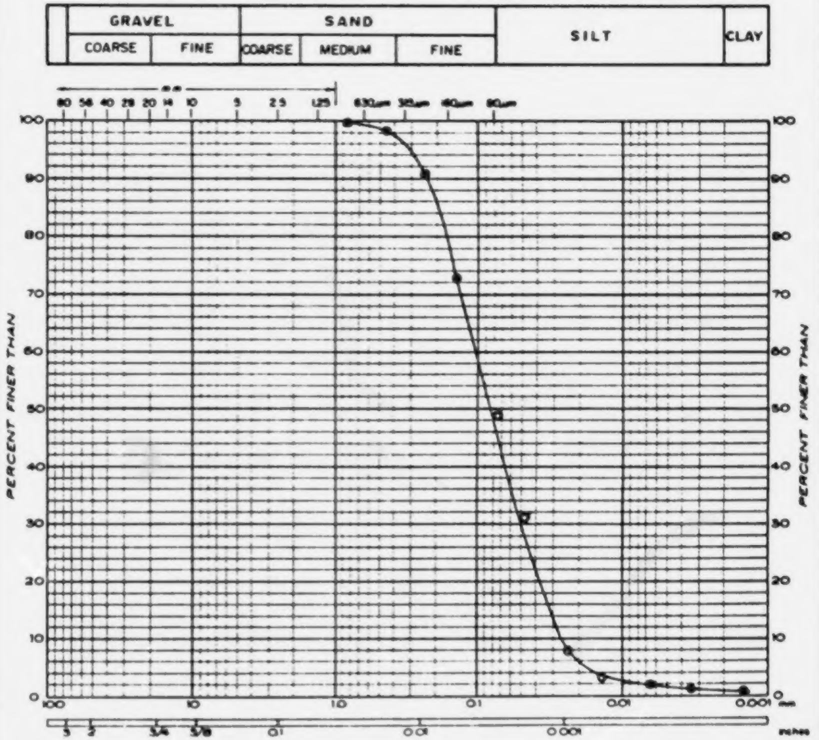
GRAIN SIZE DISTRIBUTION

Test Hole No. N1C Depth 10.7m to 11.3m
Sample No. 38

DRAWING NO



D_{60}: 0.1 mm D_{30}: 0.05 mm D_{10} : 0.025 mm

TAILINGS

REMARKS SAND - very silty, wet, medium dense, fine, poorly graded, medium reddish brown. (2nd trial - 1st trial flocculated)

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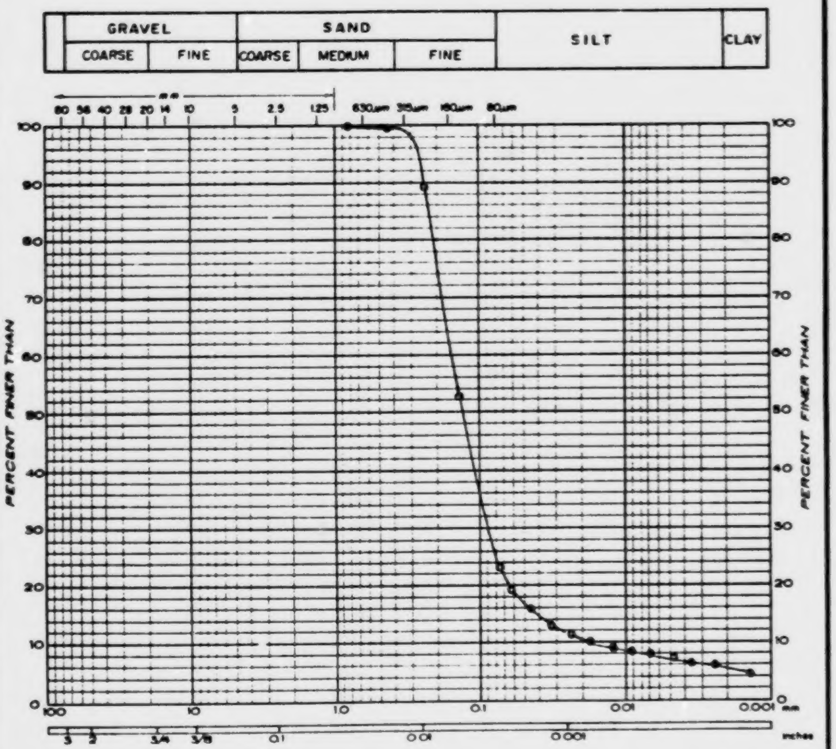
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N1C Depth 11.3m to 11.8m
Sample No. 59

DRAWING NO



TAILINGS

D_{60}: 0.15 mm D_{30}: 0.09mm D_{10}: 0.019 mm

REMARKS SAND- silty, moist, medium dense, poorly graded, medium reddish brown.

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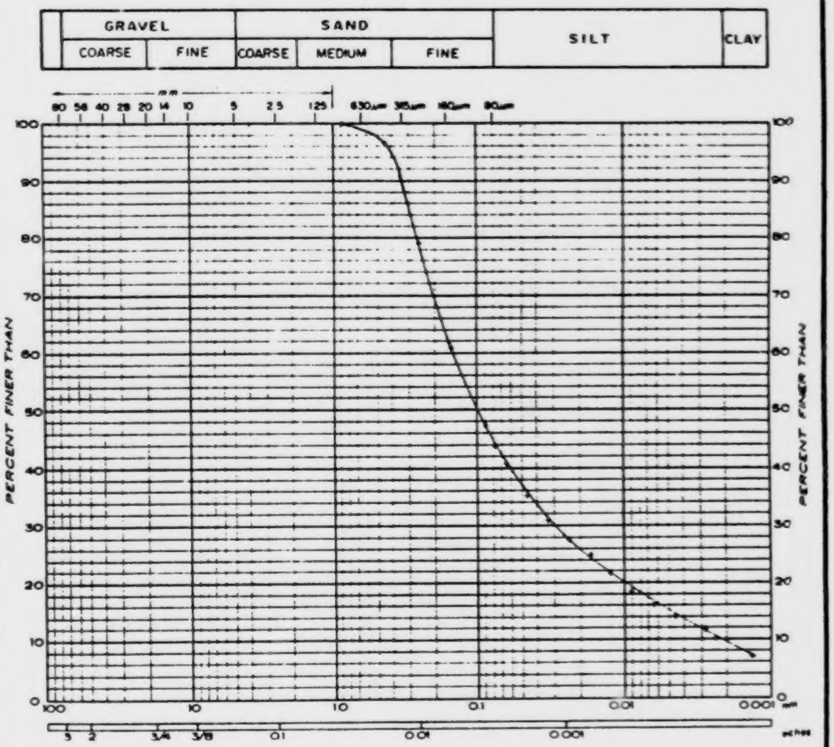
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N/D Depth 3.1m to 3.7m
Sample No S1
DRAWING NO



TAILINGS

D_{60}: 0.14 D_{30}: 0.030 D_{10}: 0.0023

REMARKS SAND: frozen, poorlygraded, fine, reddish brown, considerable silt

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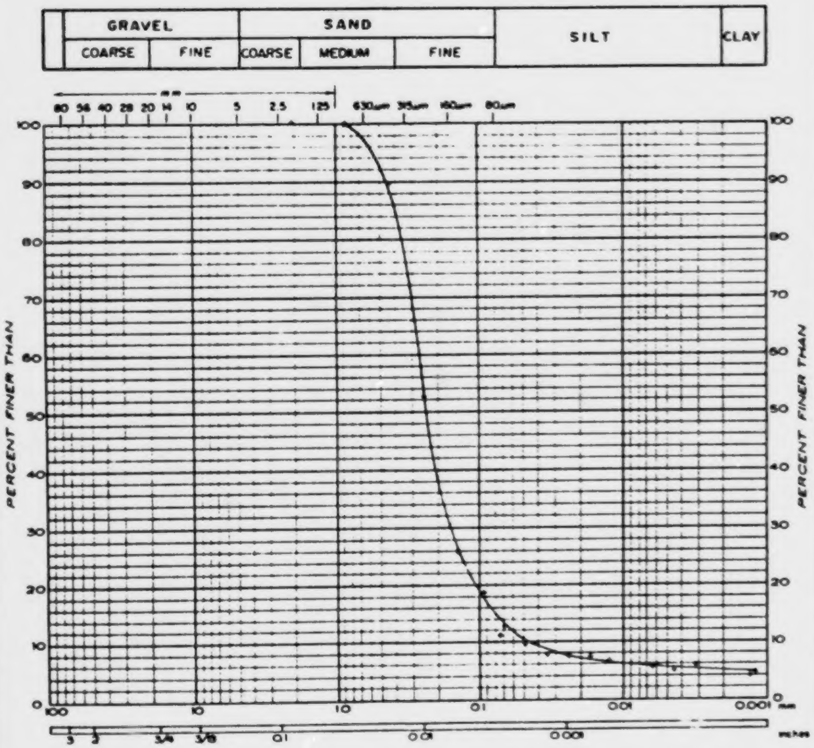
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N/E Sample No 1
Depth 0 to 0.3m
DRAWING NO



D_{60}: 0.28 D_{30}: 0.17 D_{10}: 0.045

TAILINGS

REMARKS SAND: damp, poorly graded, fine size, reddish brown

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NATIONAL URANIUM TAILINGS PROGRAM
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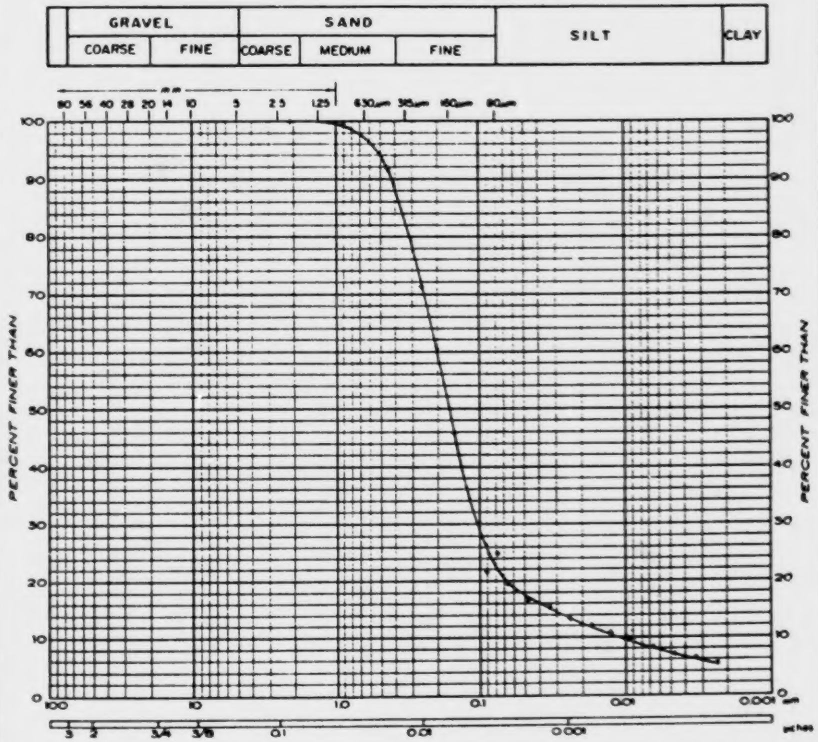
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N/E Sample No. 4
Depth 1.5m to 1.8m

DRAWING NO



D_{60}: 0.20 D_{30}: 0.10 D_{10}: 0.01

TAILINGS

REMARKS SAND: damp, poorly graded, fine size, reddish brown

GBT Geotechnical Consultants Ltd.

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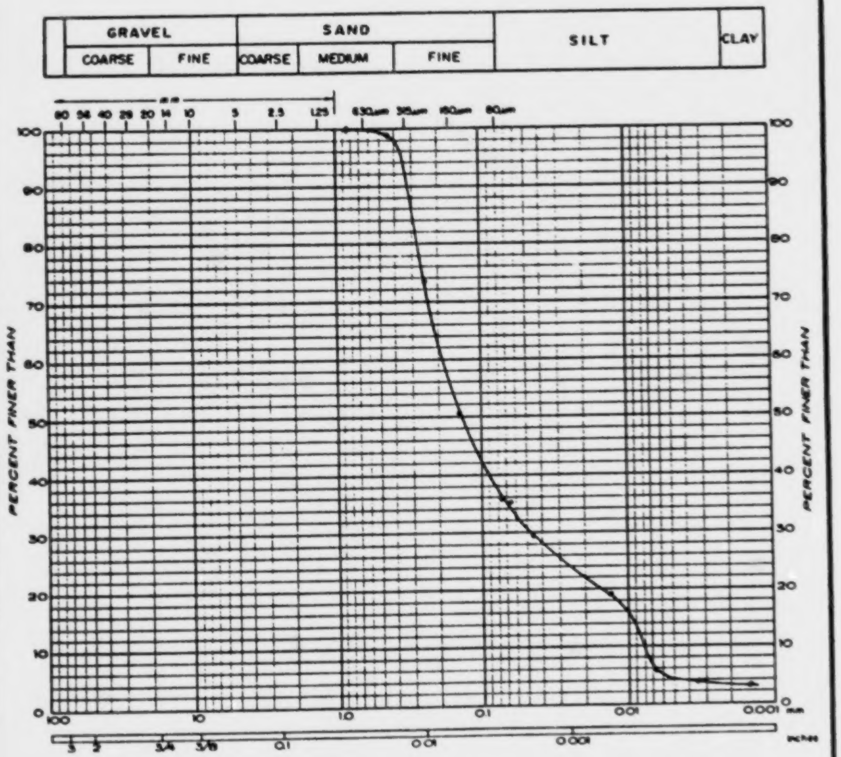
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N/E Sample No. 6
Depth 2.1m

DRAWING NO



D_{60}: 0.19 D_{30}: 0.045 D_{10}: 0.008

TAILINGS

REMARKS SAND: damp, poorly graded, fine size, reddish brown, silty.

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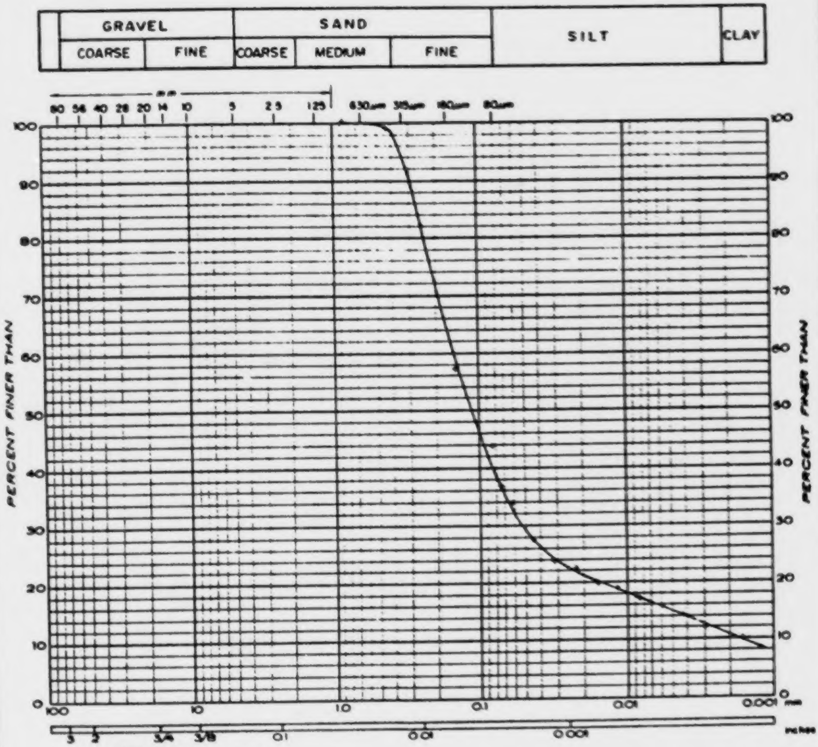
GRAIN SIZE DISTRIBUTION

Test Hole No. N1E Sample No. 2
Depth 4.2

DRAWING NO.



TAILINGS

D_{60}: 0.15 D_{30}: 0.05 D_{10}: 0.0017

IN LABORATORY CHECK

REMARKS SAND: damp, poorly graded, fine size, reddish brown, silty.

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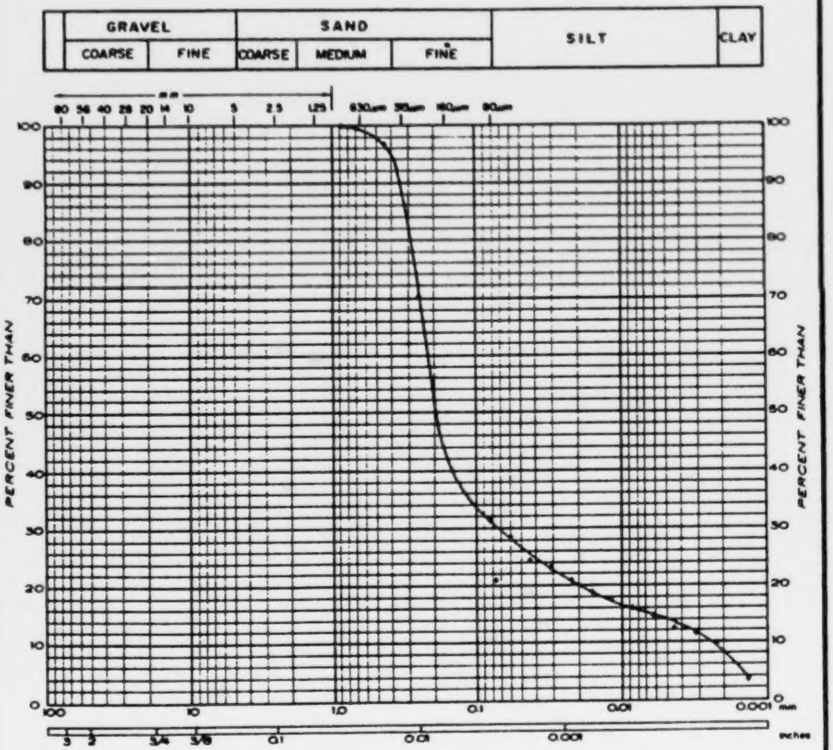
GRAIN SIZE DISTRIBUTION

Test Hole No. N1E Sample No. 9
Depth 4.2

DRAWING NO.



TAILINGS

D_{60}: 0.22 D_{30}: 0.075 D_{10}: 0.0024

REMARKS SAND: damp, poorly graded, fine size, reddish brown, silty

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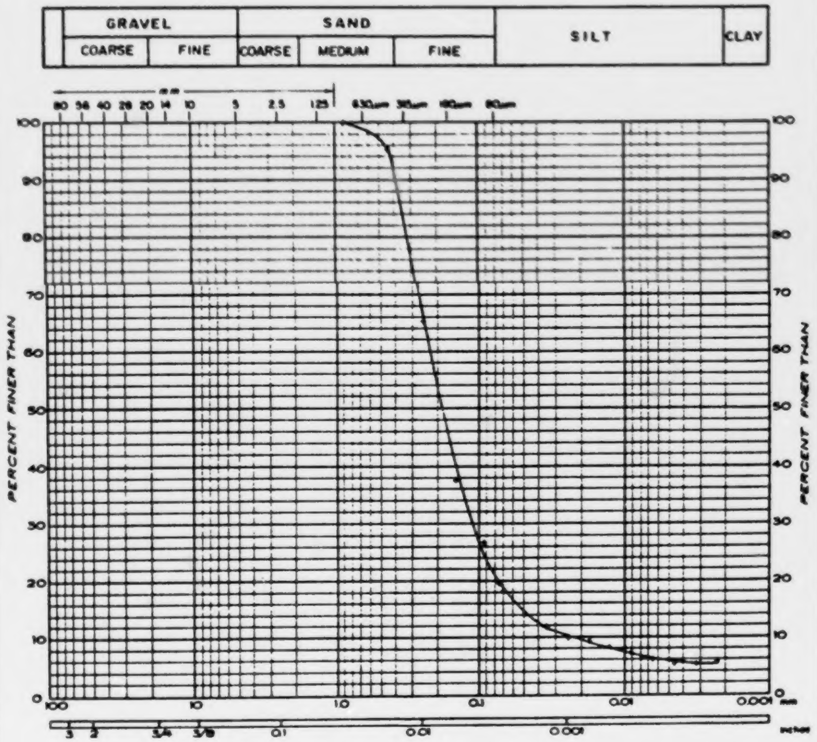
GRAIN SIZE DISTRIBUTION

Test Hole No. N.1.E. Sample No. 10
Depth 4.6m

DRAWING NO.



TAILINGS

D_{60}: 0.23 D_{30}: 0.12 D_{10}: 0.024

REMARKS SAND: moist, poorly graded, fine size, reddish brown

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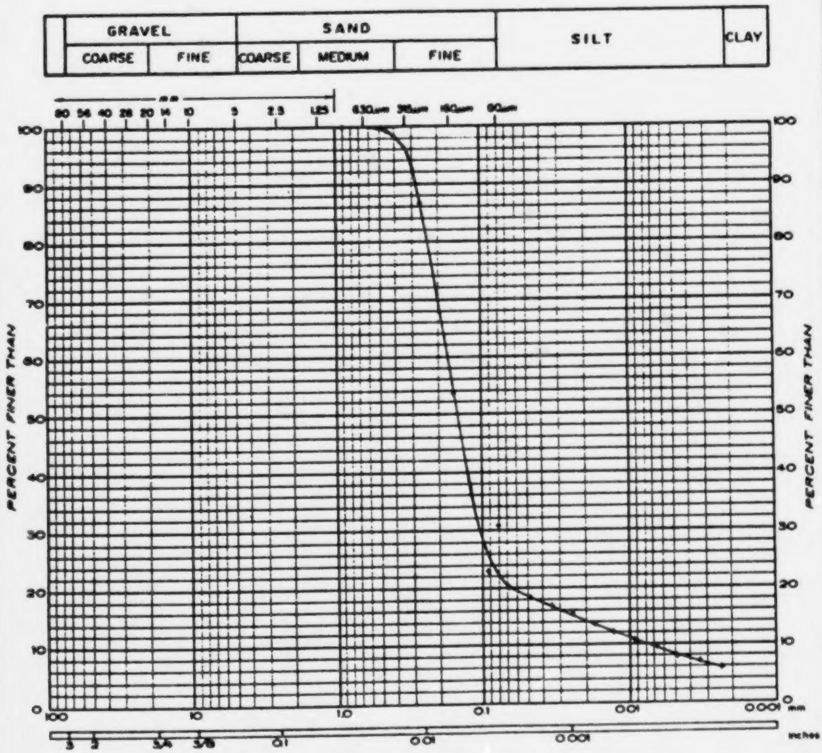
GRAIN SIZE DISTRIBUTION

Test Hole No. N1E Sample No. 13
Depth 8.6m to 9.2m

DRAWING NO.



TAILINGS

D_{60}: 0.18 D_{30}: 0.10 D_{10}: 0.008

REMARKS SAND, moist, poorly graded, fine size, reddish brown

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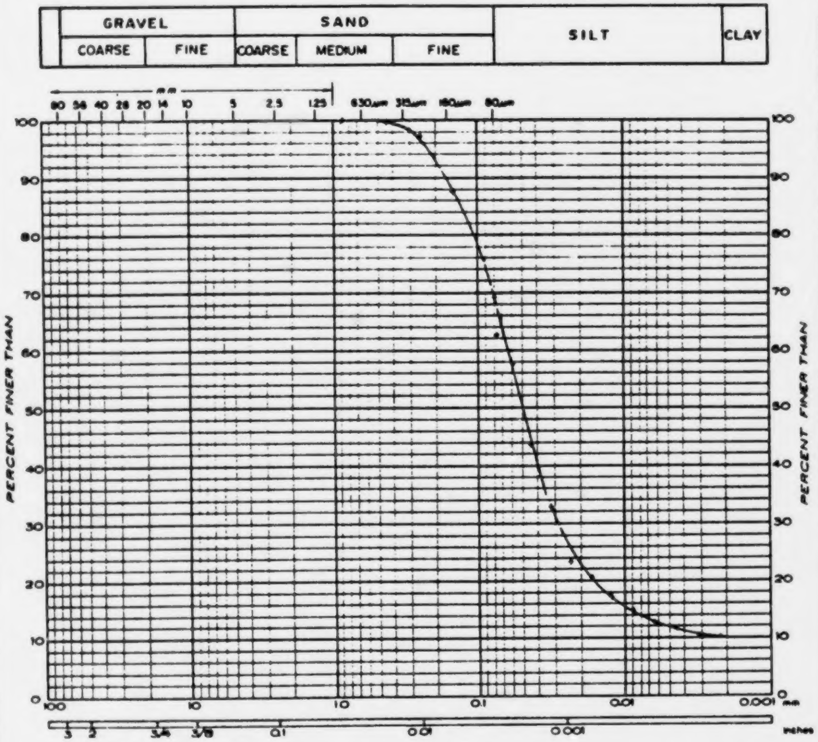
GRAIN SIZE DISTRIBUTION

Test Hole No. N/E Sample No. 14
Depth 9.2m

DRAWING NO.



TAILINGS

D_{60}: 0.064 D_{30}: 0.03 D_{10}: 0.002

REMARKS SILT: very sandy, moist, stiff, low plastic, reddish brown.

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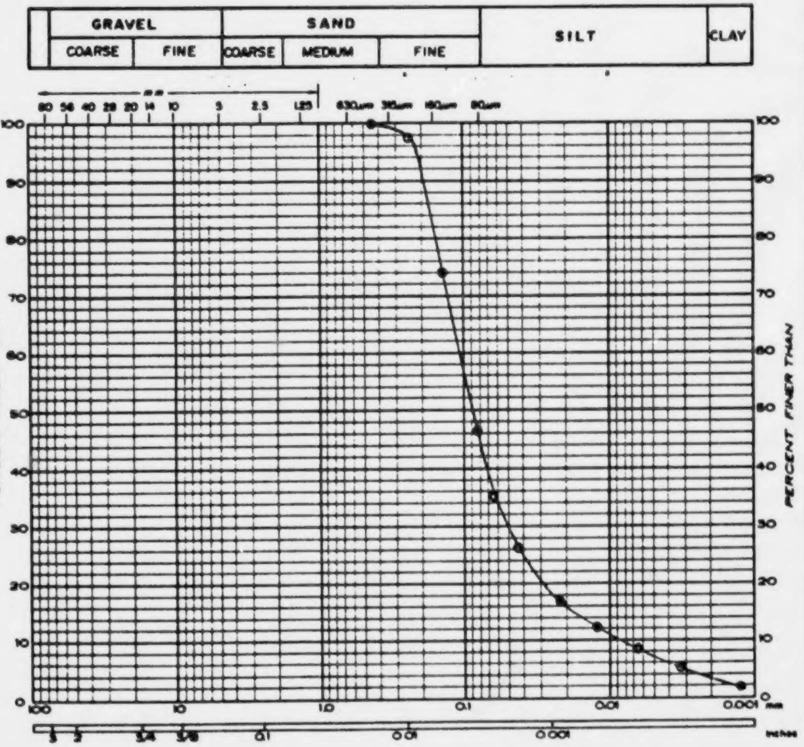
GRAIN SIZE DISTRIBUTION

Test Hole No. N/E Sample No. 17
Depth 12.4 to 13.9

DRAWING NO.



TAILINGS

D_{60} = 0.1mm D_{30} = 0.05mm D_{10} = 0.0087mm

REMARKS SAND - some silt, moist to wet, medium dense, fine, poorly graded, medium to dark brown, trace of clay

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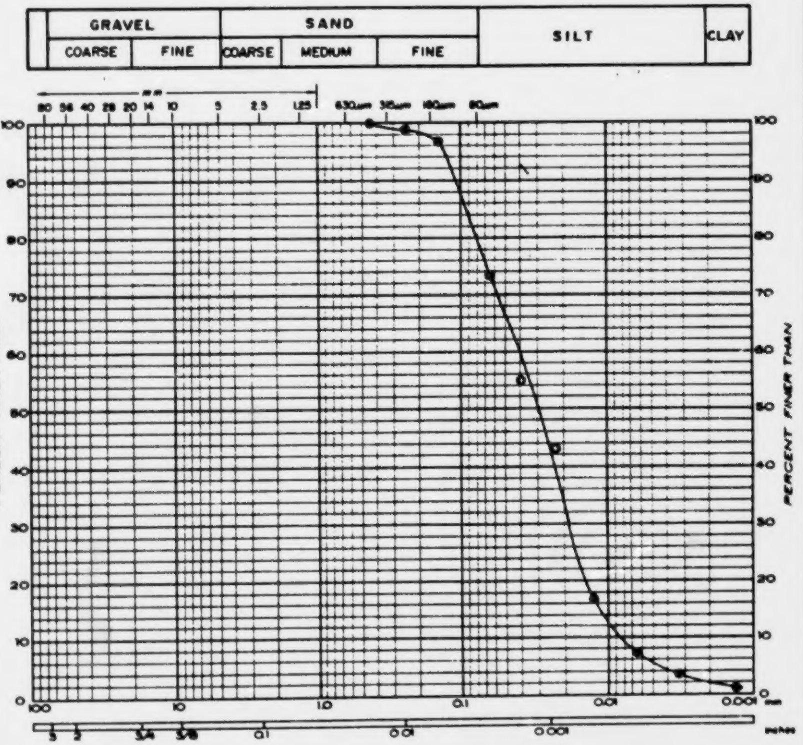
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N2A Depth 4.9 to 5.5m
Sample No 52

DRAWING NO



TAILINGS

D_{60} = 0.04mm D_{30} = 0.019mm D_{10} = 0.0083mm

REMARKS SILT - very sandy, moist to wet, stiff, non plastic, medium reddish brown

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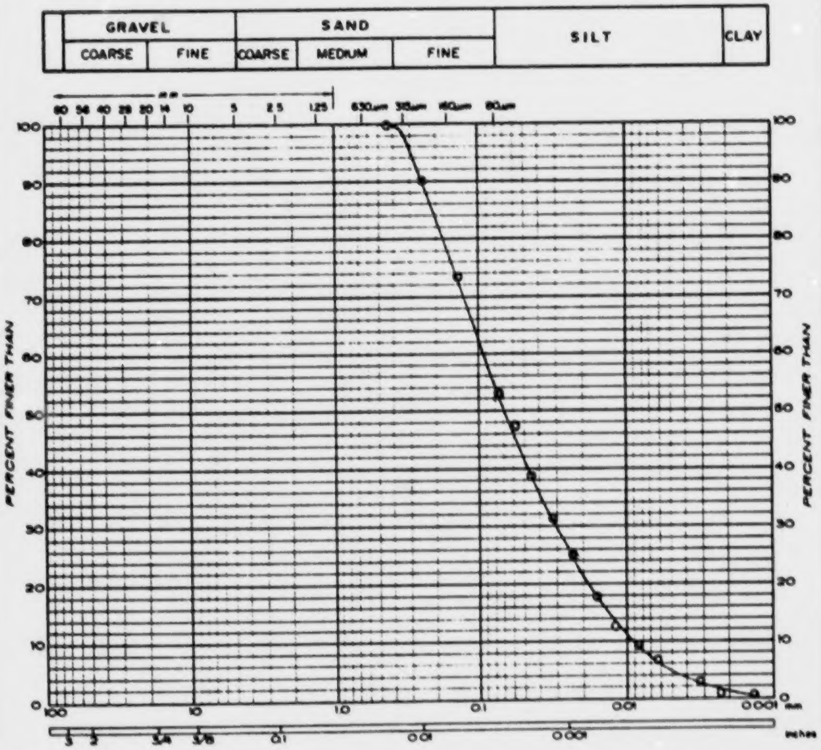
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N2B Depth 3 to 3.7m
Sample No 53

DRAWING NO



D_{60}: 0.093 mm D_{30}: 0.03mm D_{10}: 0.0092mm

TAILINGS

REMARKS SAND: very silty, moist, medium dense, poorly graded, medium reddish brown

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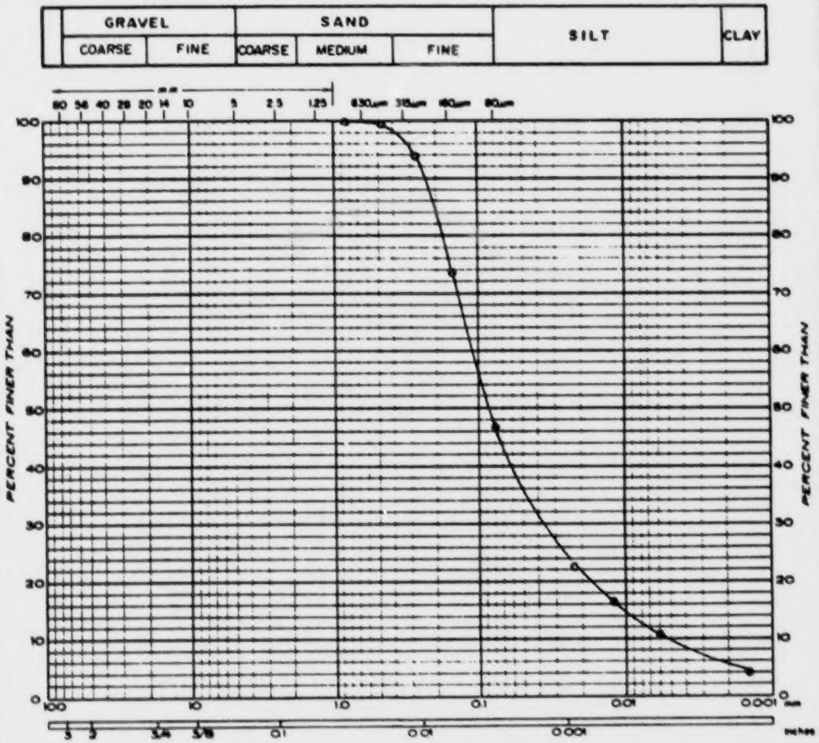
GRAIN SIZE DISTRIBUTION

Test Hole No N2C Depth 1.5 to 2.1m
Sample No 34

DRAWING NO



D_{60}: 0.11mm D_{30}: 0.035mm D_{10}: 0.0057mm

TAILINGS

REMARKS SAND: very silty, moist, medium dense, poorly graded, medium reddish brown (duplicate sample)

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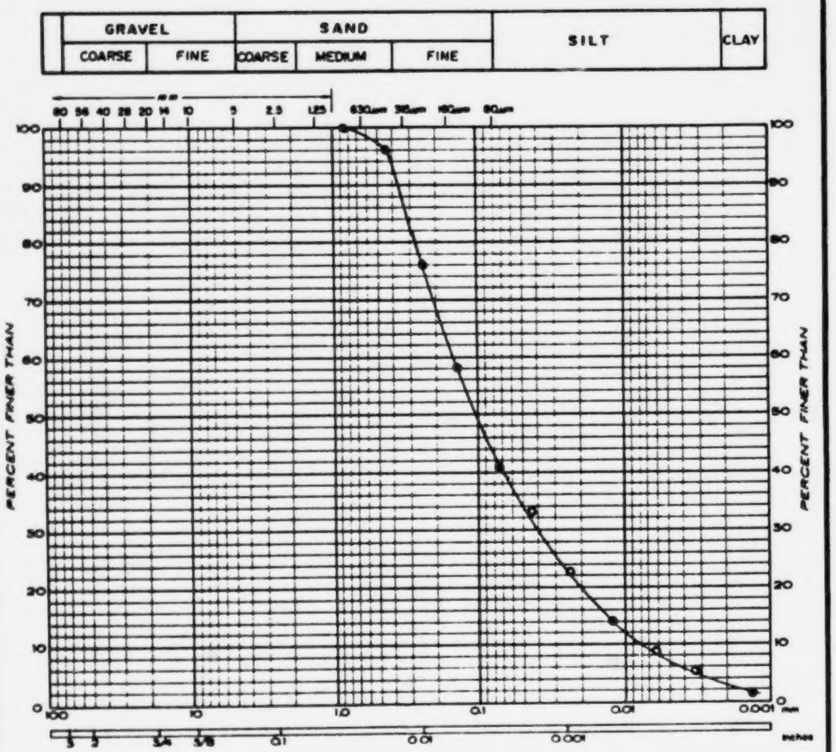
GRAIN SIZE DISTRIBUTION

Test Hole No N2C Depth 1.5 m. To 2.1m
Sample No 34B

DRAWING NO



TAILINGS

D_{60}: 0.15mm D_{30}: 0.04mm D_{10}: 0.0082mm

REMARKS SAND - damp, medium dense, poorly graded, fine size, reddish brown, some silt

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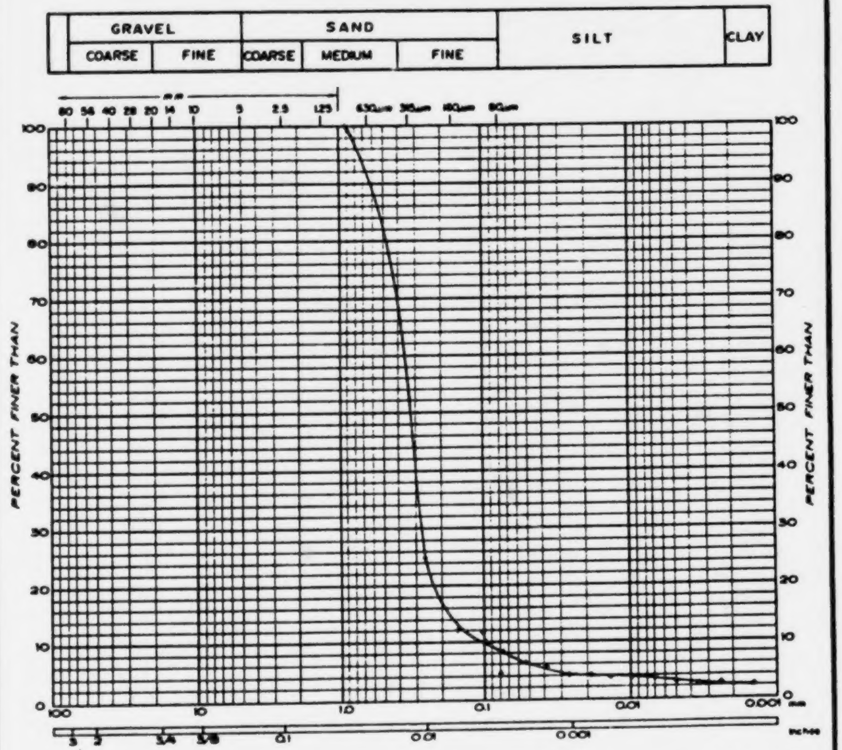
GRAIN SIZE DISTRIBUTION

Test Hole No N2D Depth 0.6-1.2m
Sample No S5

DRAWING NO



TAILINGS

D_{60}: 0.37 D_{30}: 0.030 D_{10}: 0.10

REMARKS SAND - moist, poorly graded, fine size, reddish brown

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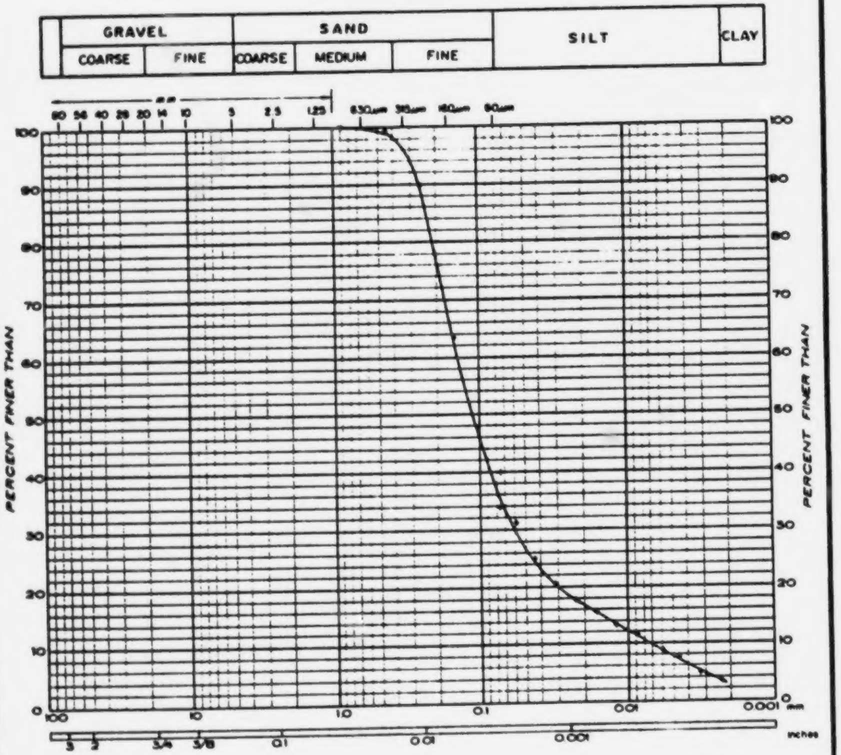
GRAIN SIZE DISTRIBUTION

Test Hole No N2E Sample No 1
Depth 0

DRAWING NO.



TAILINGS

D_{60}: 0.14 D_{30}: 0.055 D_{10}: 0.008

REMARKS SAND - poorly graded, fine, reddish brown, silty

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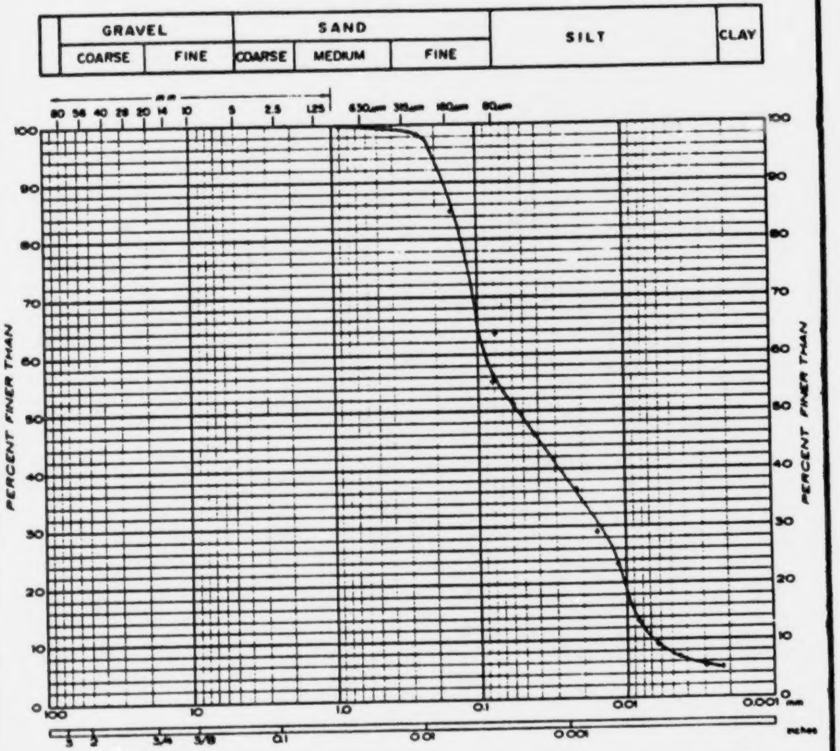
GRAIN SIZE DISTRIBUTION

Test Hole No. N3E Sample No. 4
Depth 2.4 m

DRAWING NO



TAILINGS

D_{60}: 0.09 D_{30}: 0.015 D_{10}: 0.0065

REMARKS SILT - sandy, saturated, poorly graded, fine, reddish brown

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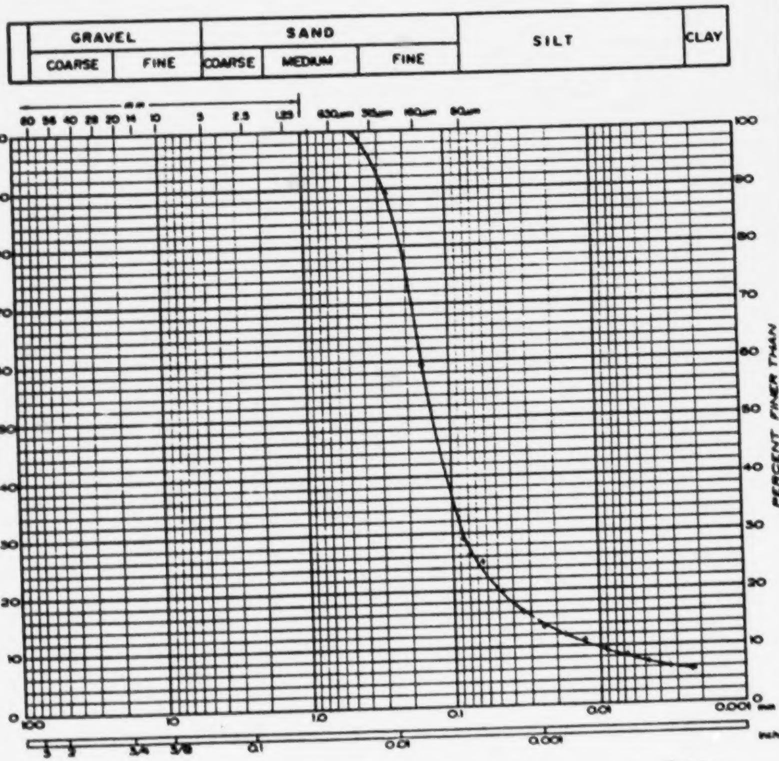
GRAIN SIZE DISTRIBUTION

Test Hole No. N2E Sample No. 6
Depth 3.4 m

DRAWING NO.



TAILINGS

D_{60}: 0.15 D_{30}: 0.09 D_{10}: 0.01

REMARKS SAND - moist, poorly graded, fine size, reddish brown, silty.

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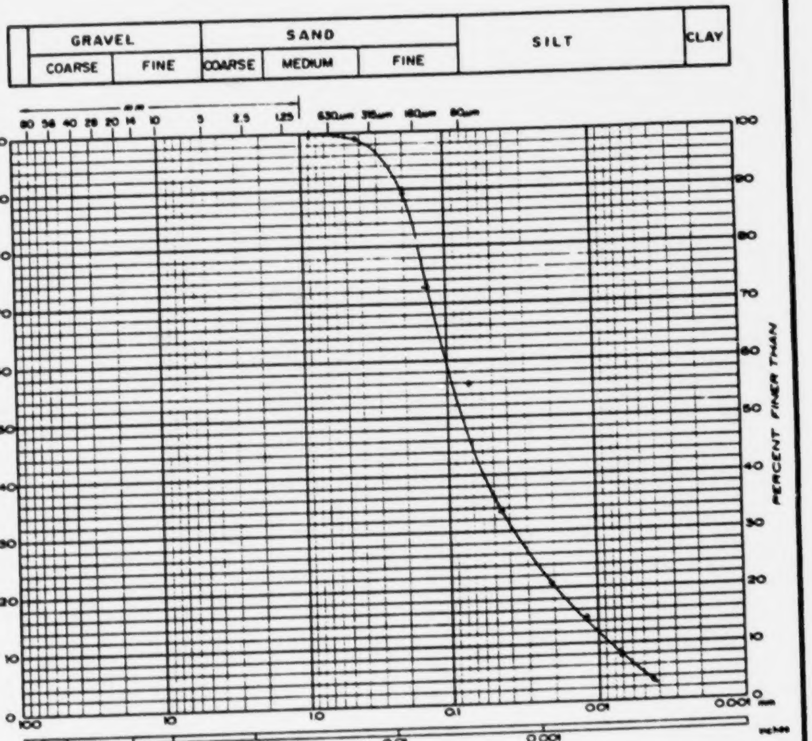
GRAIN SIZE DISTRIBUTION

Test Hole No. V.26 Sample No. 7
Depth 4.6
DRAWING NO.



TAILINGS

D_{60}: 0.13 D_{30}: 0.033 D_{10}: 0.009

REMARKS SAND silty, fine, reddish brown

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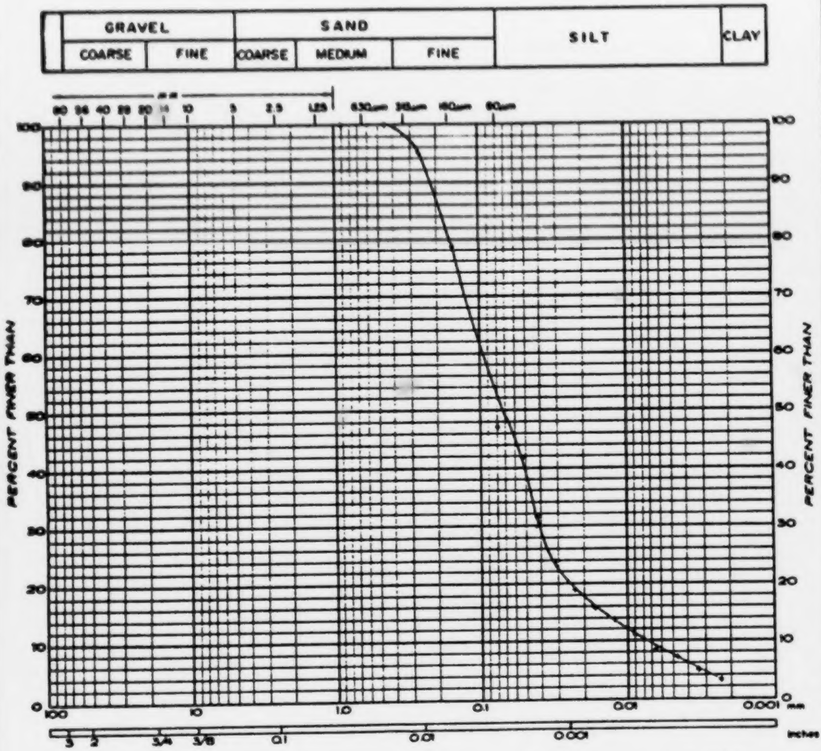
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N26 Sample No. 39
Depth 6.4m - 6.7m
DRAWING NO.



D_{60}: 0.095 D_{30}: 0.040 D_{10}: 0.008

TAILINGS

REMARKS SILT- sandy, moist, poorly graded, fine size, reddish brown
trace of clay.

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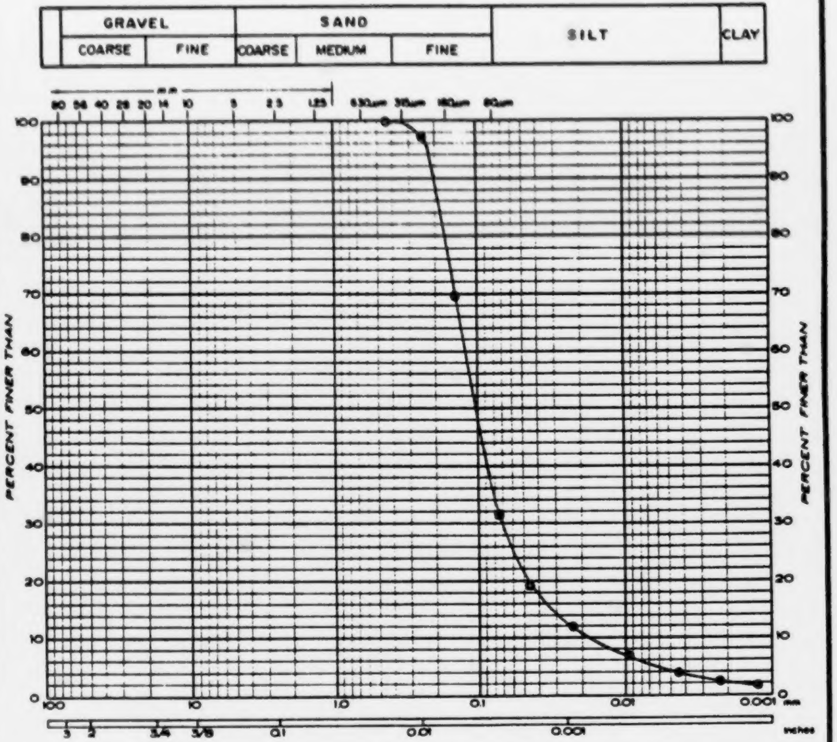
GRAIN SIZE DISTRIBUTION

Test Hole No. S2E Sample No. S10
Depth 7.5

DRAWING NO. -



D_{60} = 0.12mm D_{30} = 0.07mm D_{10} = 0.019mm

TAILINGS

REMARKS SAND- silty, moist to wet, poorly graded, medium to dark reddish brown.

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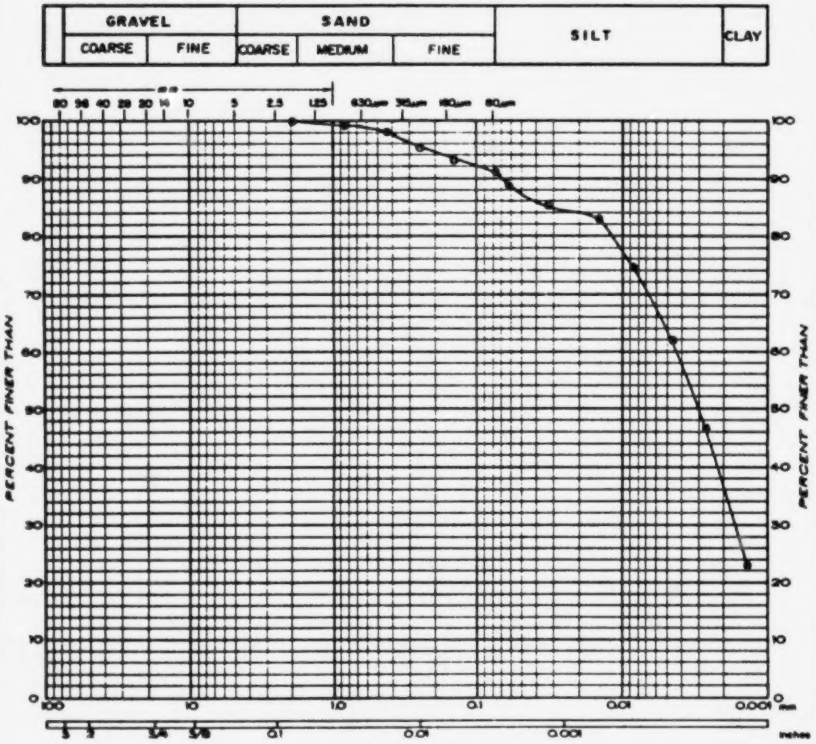
GRAIN SIZE DISTRIBUTION

Test Hole No N3E Depth 1.5 to 2.1m
Sample No 33

DRAWING NO.



NATIVE SOIL

D_{60}: 0.0042mm D_{30}: 0.0016mm D_{10}: 0.001mm

REMARKS CLAY - very silty, moist, stiff, medium plastic, light grey

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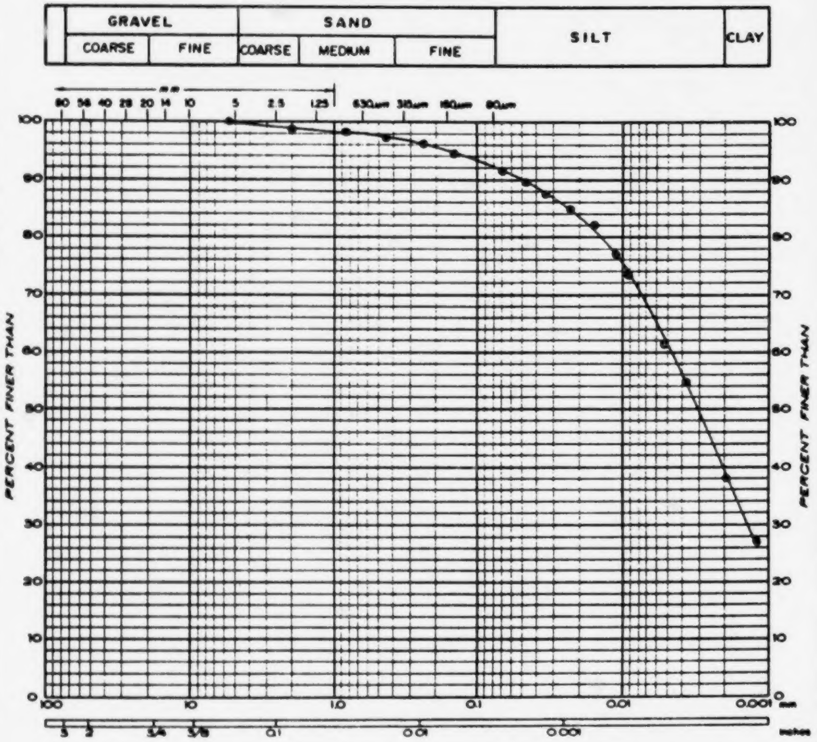
GRAIN SIZE DISTRIBUTION

Test Hole No N3E Depth 8.2 to 8.8m
Sample No S10

DRAWING NO.



NATIVE SOIL

D_{60}: 0.0045 D_{30}: 0.0014mm D_{10} = 0.0008mm

REMARKS CLAY - very silty, moist, stiff, medium plastic, light grey

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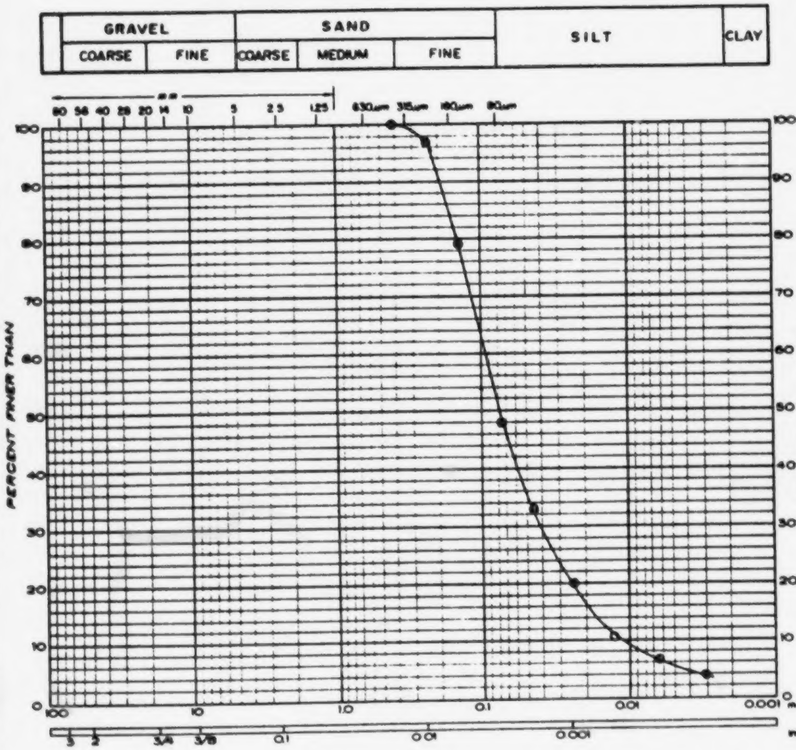
NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N3F Depth 7.3 m to 7.9m
Sample No S1

DRAWING NO.



TAILINGS

D_{60} = 0.094 mm D_{30} : 0.04 mm D_{10} : 0.011 mm

REMARKS SILT - moist, stiff, low plastic, medium reddish brown, sandy.

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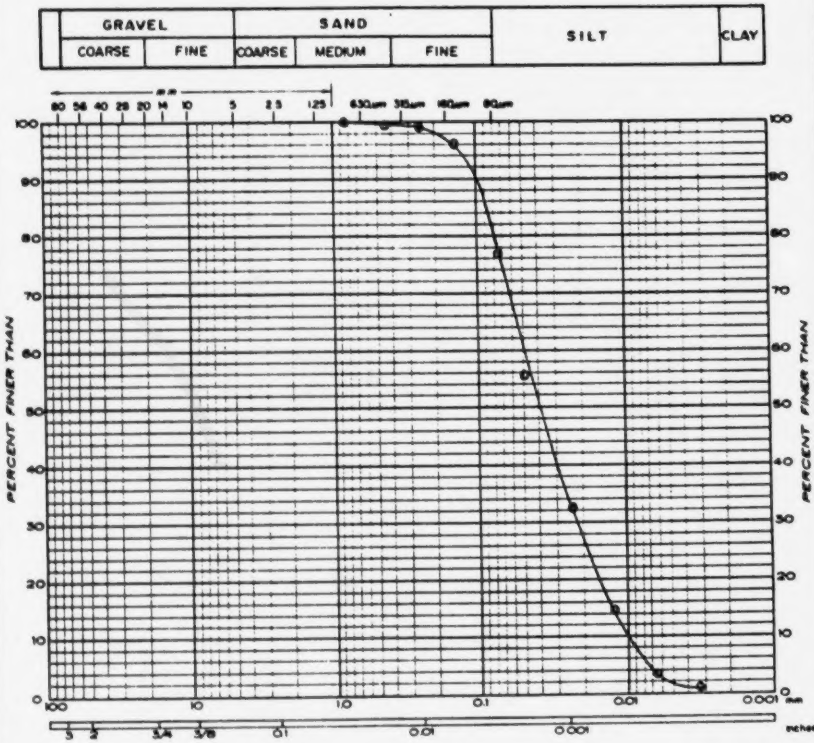
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N4A Depth 0.0.6m
Sample No S1

DRAWING NO.



TAILINGS

D_{60} : 0.049mm D_{30} : 0.021mm D_{10} : 0.01mm

REMARKS SILT - moist, stiff, low plastic, medium reddish brown.

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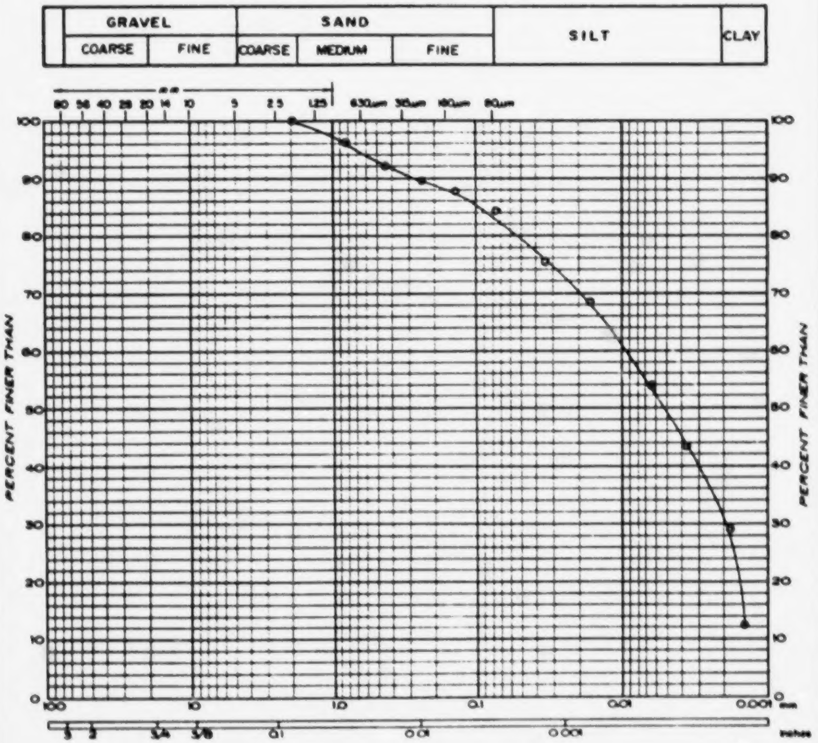
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N4A Depth 1.5 to 2.1m
Sample No S2

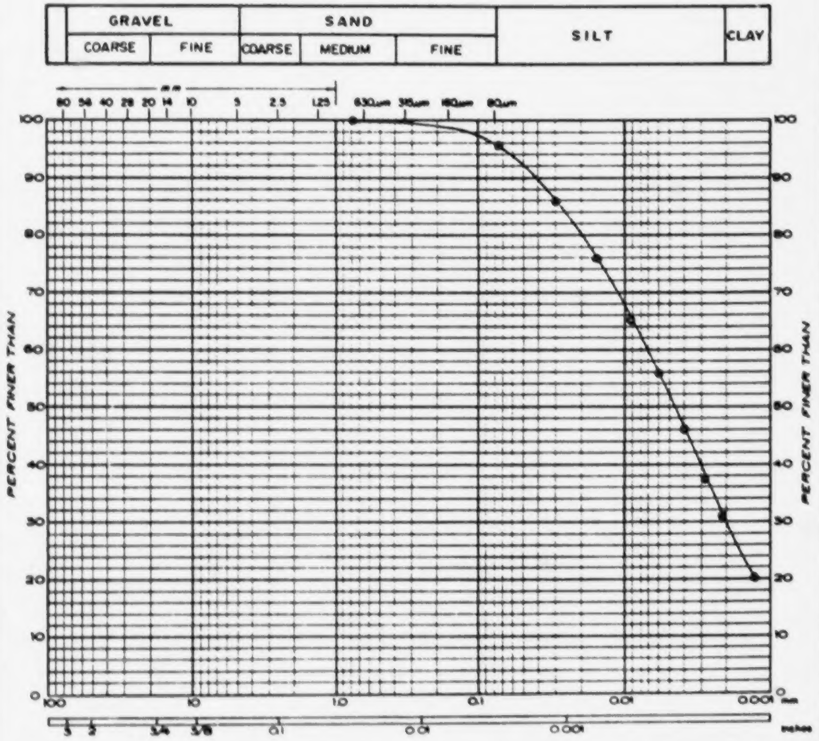
DRAWING NO.



NATIVE SOIL D_{60} = 0.0094 mm D_{30} : 0.002 mm D_{10} : 0.001 mm

REMARKS CLAY - moist, stiff, low plastic, light grey

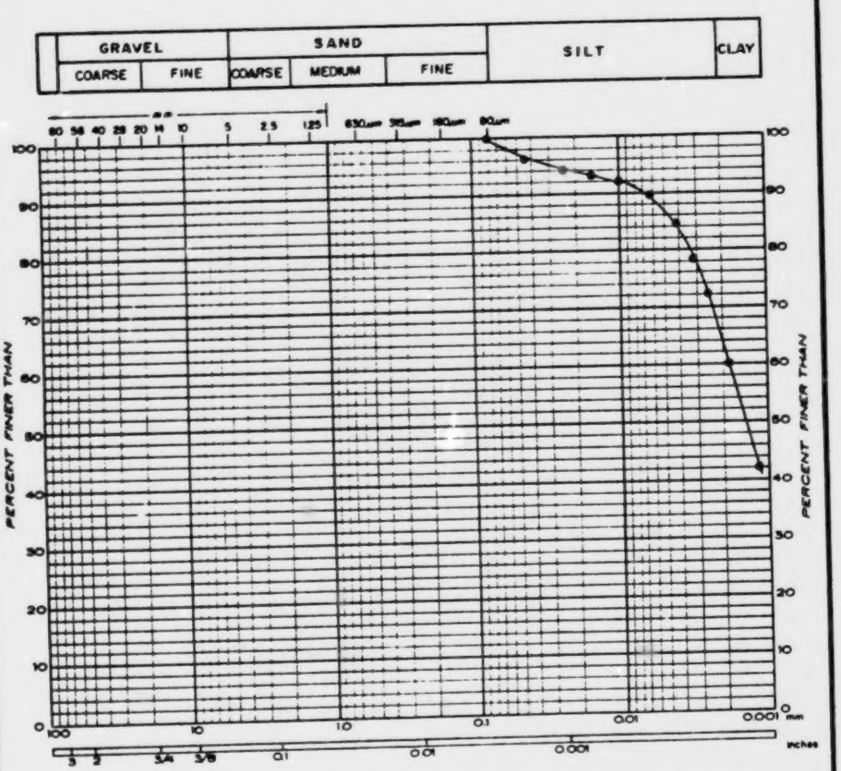
Geotechnical Consultants Ltd.	NATIONAL URANIUM TAILINGS PROGRAM GUNNAR FIELD STUDY SOUTH OF URANIUM CITY, SASKATCHEWAN
GRAIN SIZE DISTRIBUTION	Test Hole No. N4A Depth 5.2 to 5.8 m Sample No. S5
	DRAWING NO.



TAILINGS D_{60} : 0.007 mm D_{30} : 0.002 mm D_{10} : 0.0008 mm

REMARKS CLAY - very silty, stiff, low plastic, medium reddish brown

Geotechnical Consultants Ltd.	NATIONAL URANIUM TAILINGS PROGRAM GUNNAR FIELD STUDY SOUTH OF URANIUM CITY, SASKATCHEWAN
GRAIN SIZE DISTRIBUTION	Test Hole No. N4B Depth 1.8 m to 2.4 m Sample No. S1
	DRAWING NO.



NATIVE SOIL D_{60} = 0.0018mm D_{30} = 0.001mm D_{10} = 0.0005 mm

REMARKS CLAY - stiff, low plastic, light grey

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NATIONAL URANIUM TAILINGS PROGRAM
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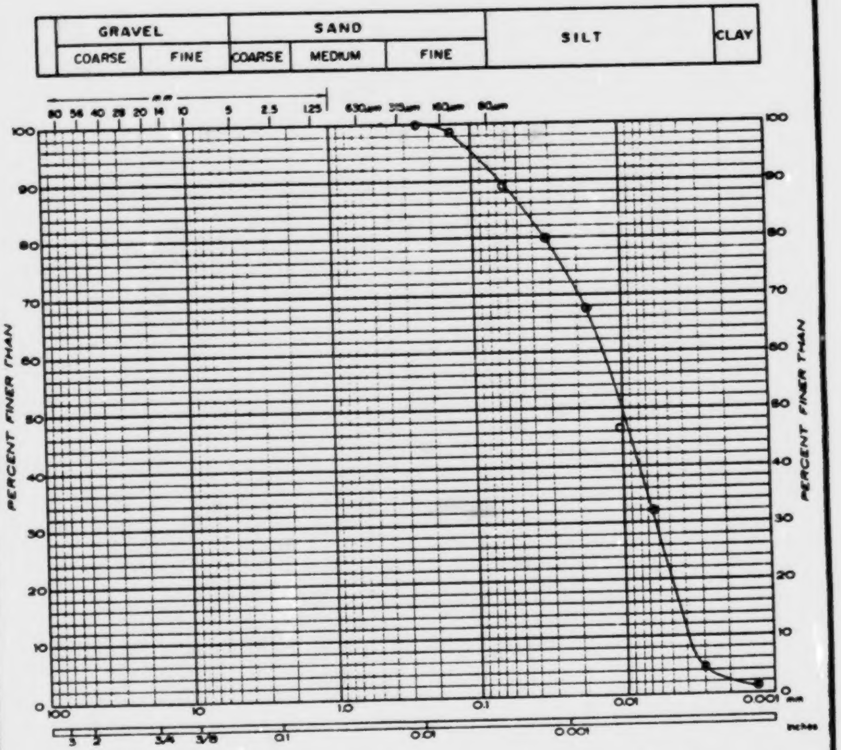
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N.4.B. Depth 3.0 m to 3.7m
Sample No S2

DRAWING NO.



TAILINGS D_{60} = 0.014mm D_{30} = 0.0073mm D_{10} = 0.0039mm

REMARKS SILT - moist, firm, low plastic, medium reddish brown.

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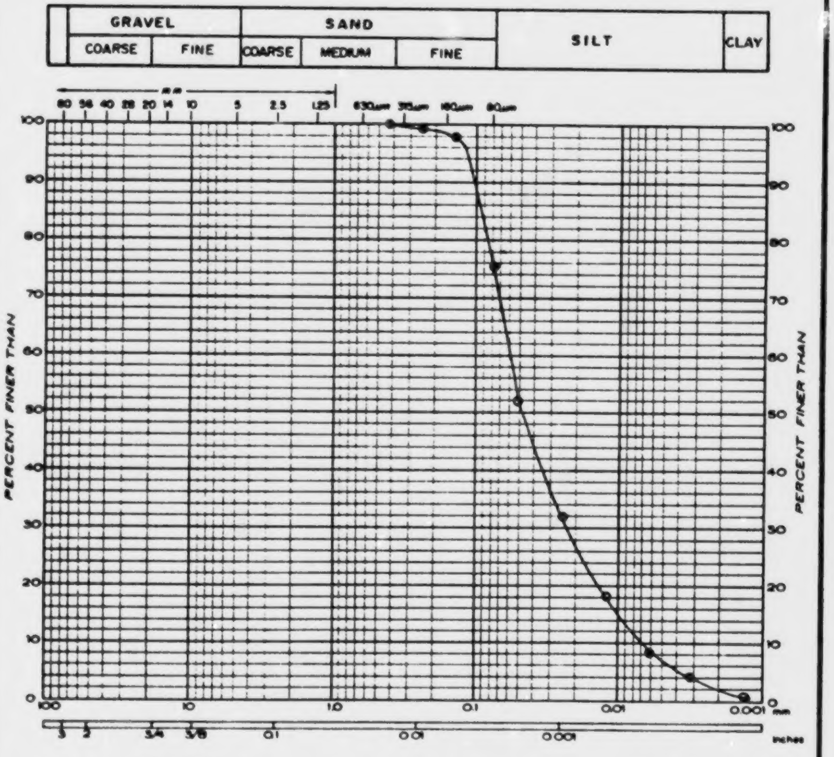
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N5A Depth 0 to 0.6m
Sample No S1

DRAWING NO.



TAILINGS

D_{60} = 0.06mm D_{30} = 0.023mm D_{10} = 0.0069mm

REMARKS SILT - moist, firm, low plastic, medium reddish brown

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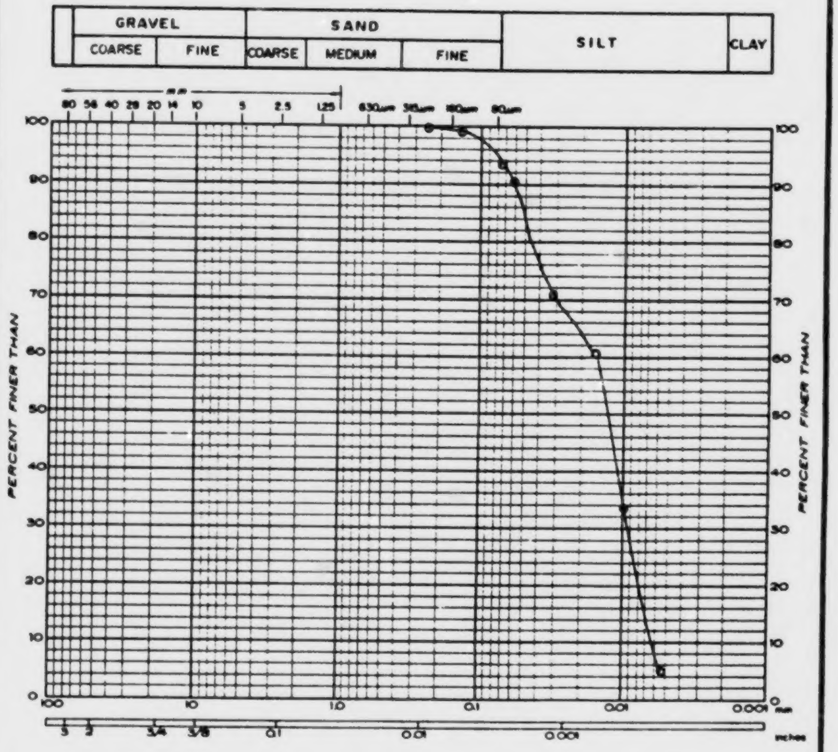
NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N5A Depth 1.2 to 1.8m
Sample No. S2

DRAWING NO.



TAILINGS

D_{60} = 0.015 mm D_{30} = 0.0093mm D_{10} = 0.0062mm

REMARKS SILT - moist, firm, low plastic, medium reddish brown, trace of clay, - flocculated with 3X standard amount of deflocculating agent.

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NATIONAL URANIUM TAILINGS PROGRAM
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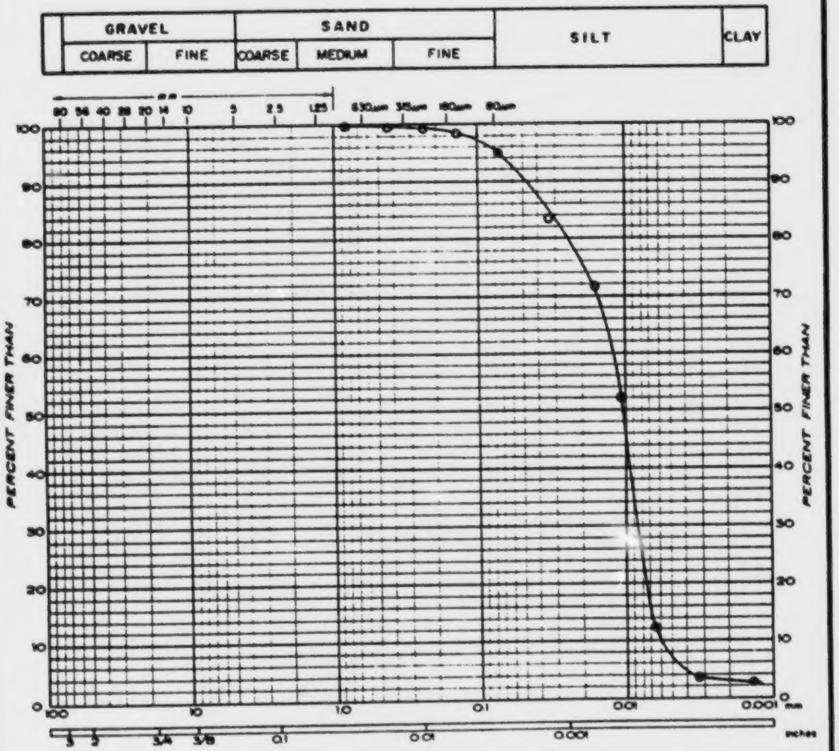
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N5A Depth 2.1m to 2.7
Sample No. S3

DRAWING NO.



TAILINGS

D_{60}: 0.013mm D_{30}: 0.0085mm D_{11}: 0.006mm

REMARKS SILT - moist, firm, non plastic, medium reddish brown

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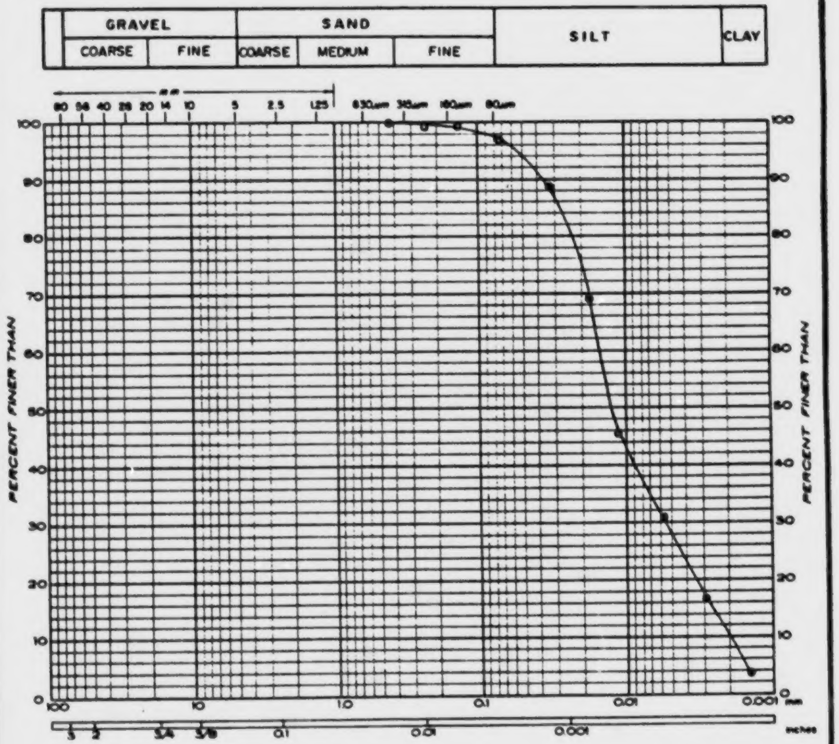
GRAIN SIZE DISTRIBUTION

Test Hole No N5A Depth 3 to 3.7m
Sample No S4

DRAWING NO.



NATIVE SOIL

D_{60}: 0.015mm D_{30}≈0.0055mm D_{10}: 0.002mm

REMARKS CLAY - moist, stiff, medium plastic, medium gray

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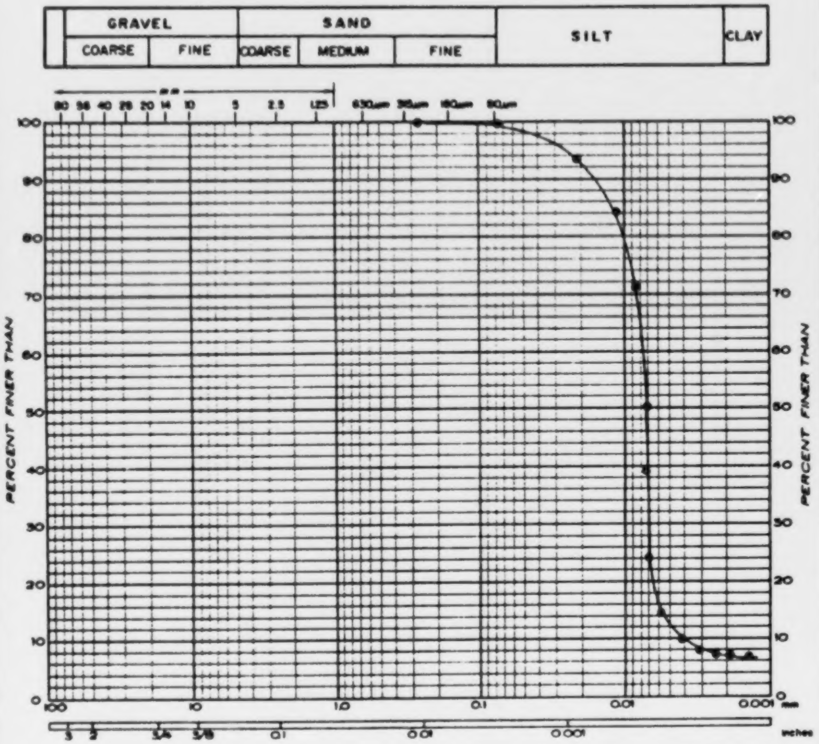
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No N5A Depth 12.2 to 12.8m
Sample No S11

DRAWING NO.



TAILINGS

D_{60}: 0.0075 mm D_{30}: 0.007 mm D_{10}: 0.004 mm

REMARKS SILT- very sandy, moist, stiff, non plastic, medium reddish brown.

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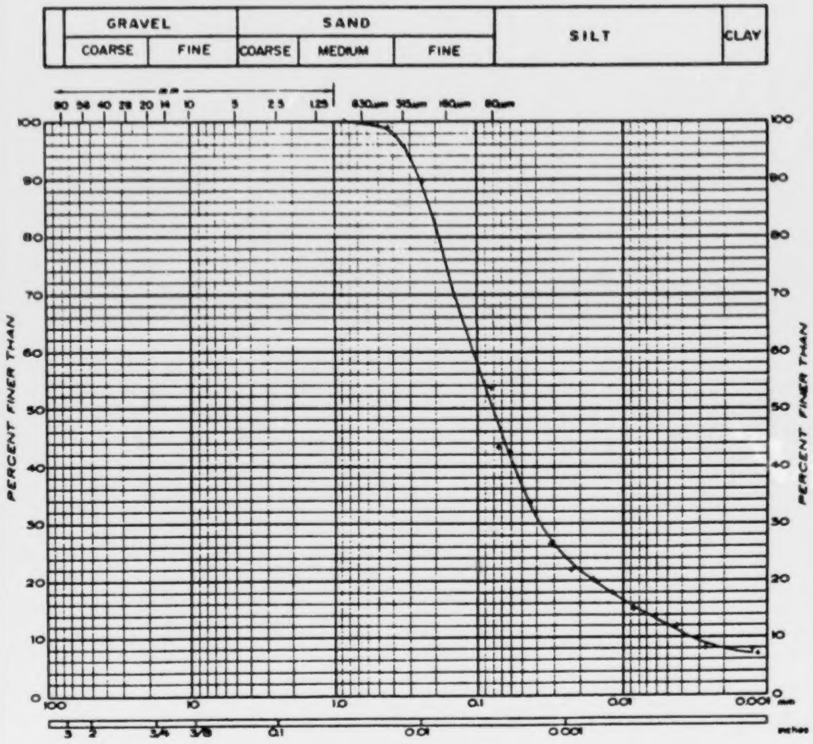
GRAIN SIZE DISTRIBUTION

Test Hole No. N5B Depth 1.8 m
Sample No. S1 to 3.4 m

DRAWING NO.



TAILINGS

D_{60}: 0.01 D_{30}: 0.038 D_{10}: 0.0033

REMARKS SAND- frozen, poorly graded, fine size, reddish brown, very silty.

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NATIONAL URANIUM TAILINGS PROGRAM
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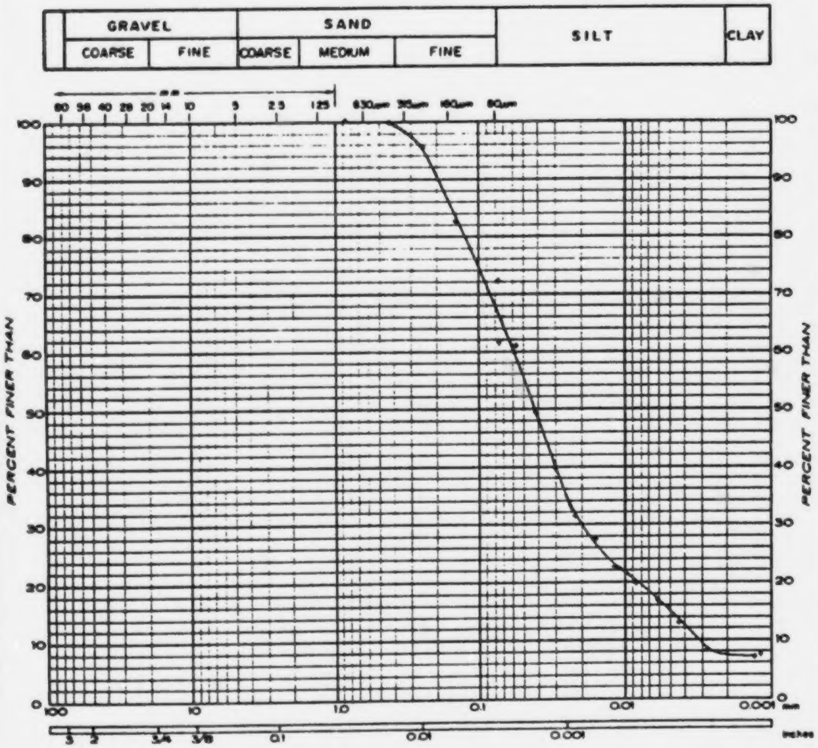
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N6A Sample No. 1
Depth 0.8m TO 0.9m

DRAWING NO.



TAILINGS

D₆₀: 0.055 D₃₀: 0.02 D₁₀: 0.0033

REMARKS SILT - very sandy, moist, stiff, non plastic, reddish brown

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NATIONAL URANIUM TAILINGS PROGRAM
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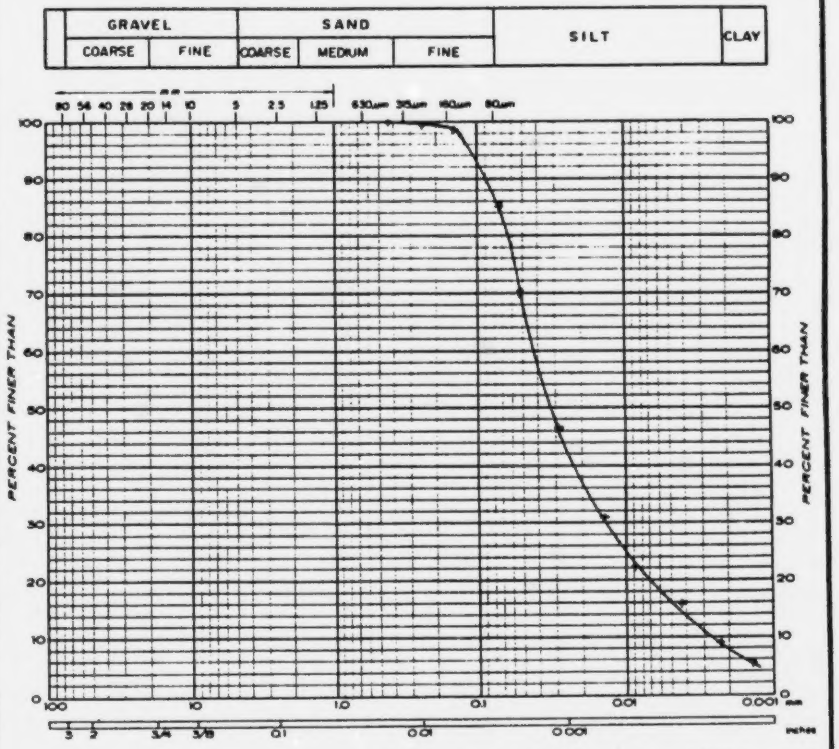
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N6A Sample No. 3
Depth 4.5m TO 4.6m

DRAWING NO.



NATIVE SOIL

D₆₀: 0.043 D₃₀: 0.014 D₁₀: 0.0024

REMARKS CLAY - moist, stiff, medium to highly plastic, grey

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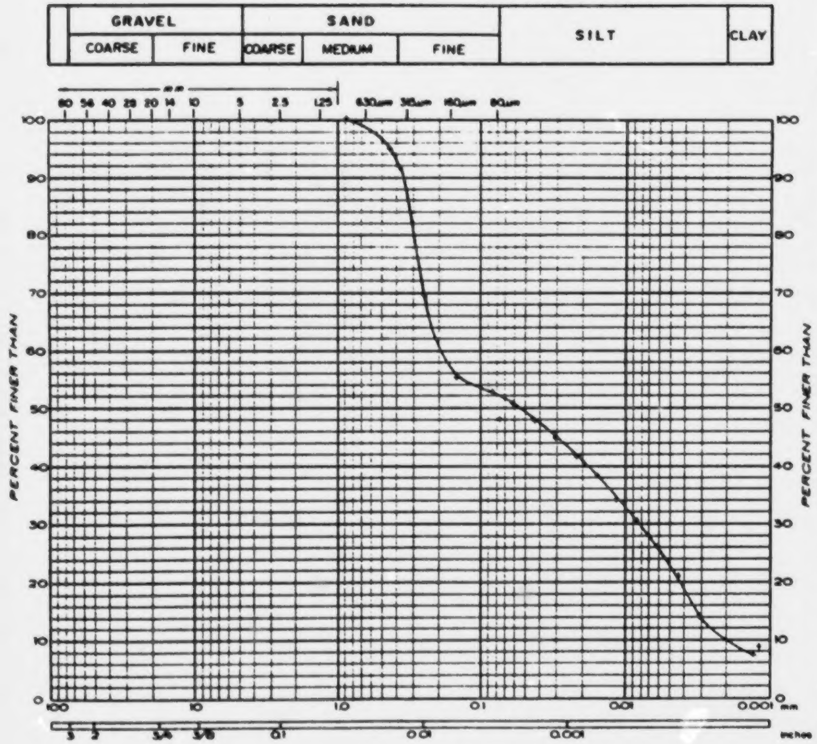
NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. N6A Sample No. 55
Depth 6.1m to 6.7m

DRAWING NO.



TAILINGS

D60: 0.19 D30: 0.0083 D10: 0.0022

REMARKS SILT - very sandy, reddish brown.

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NATIONAL URANIUM TAILINGS PROGRAM
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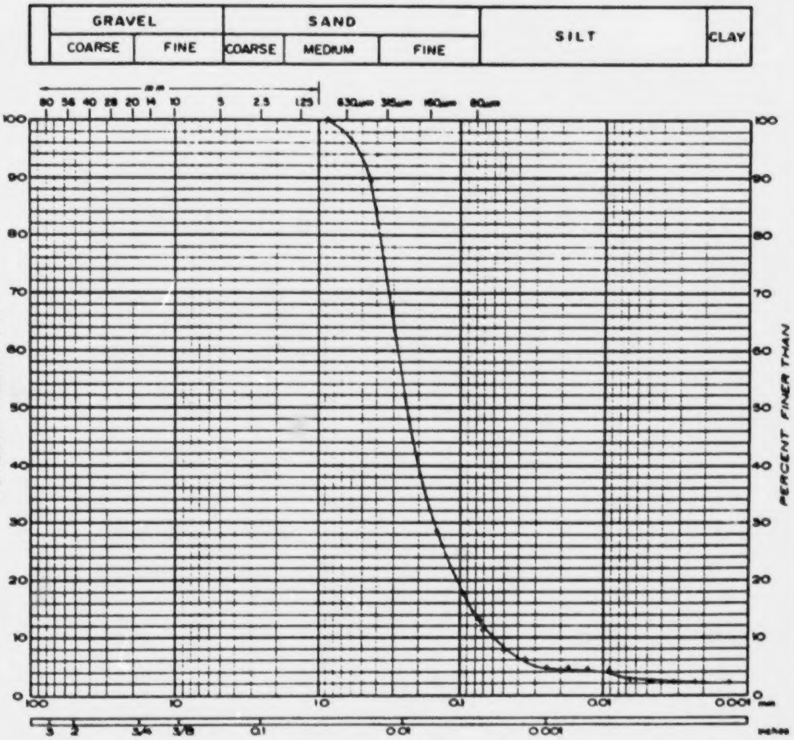
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No GM1A Sample No. 1
Depth 0 m

DRAWING NO.



TAILINGS

D60: 0.28 D30: 0.15 D10: 0.063

REMARKS SAND: damp, medium dense, poorly graded, fine, reddish brown

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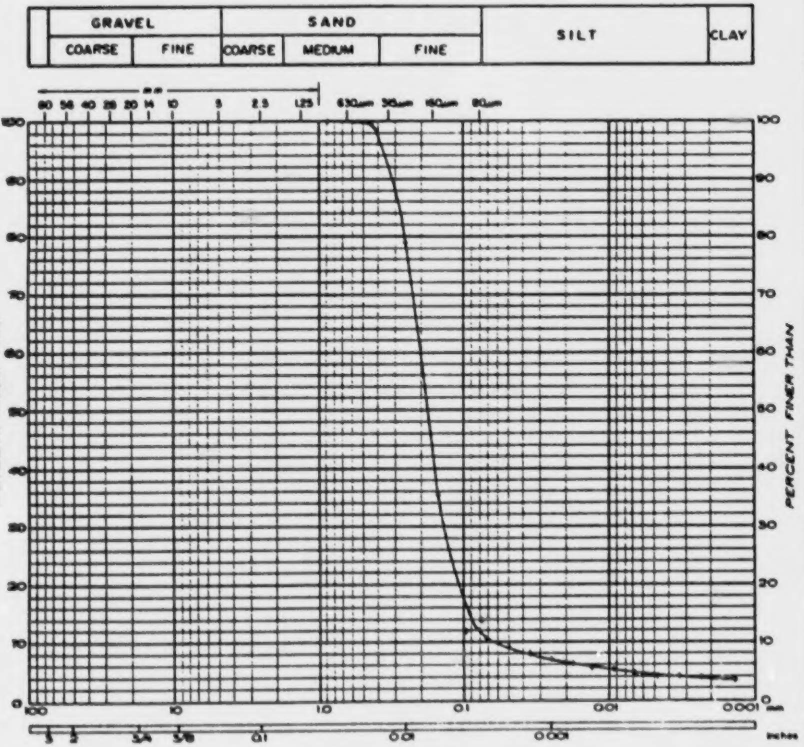
NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No GM2A Sample No. 1
Depth 0 m

DRAWING NO.



TAILINGS

D_{60}: 0.20 D_{30}: 0.13 D_{10}: 0.065

REMARKS SAND - damp, poorly graded, fine, reddish brown.

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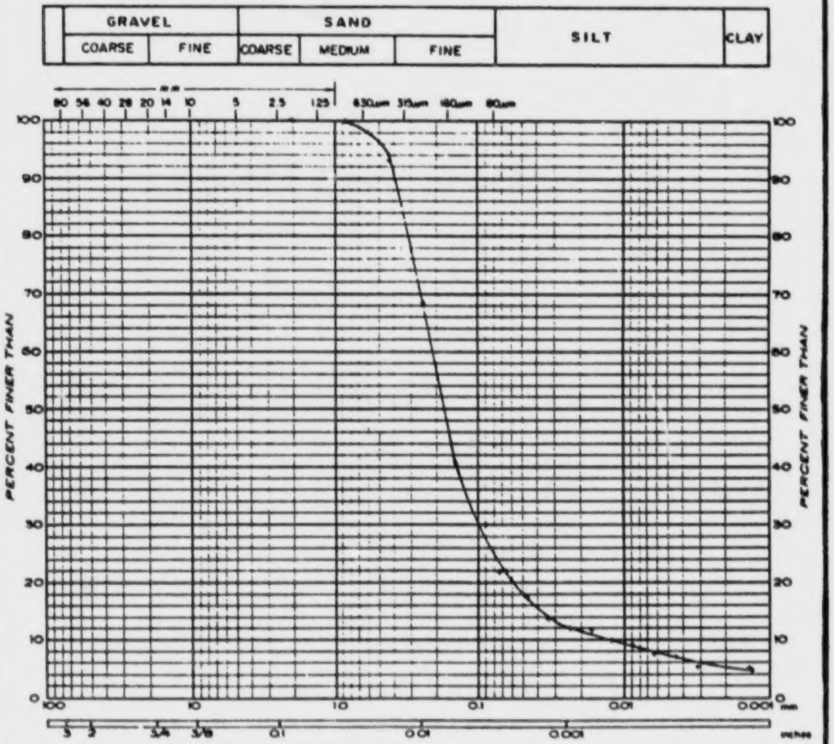
GRAIN SIZE DISTRIBUTION

Test Hole No. GM21 Sample No. 1
Depth 3.0m

DRAWING NO.



TAILINGS

D_{60}: 0.20 D_{30}: 0.09 D_{10}: 0.013

REMARKS SAND - damp to moist, medium dense, poorly graded, fine, reddish brown, silty.

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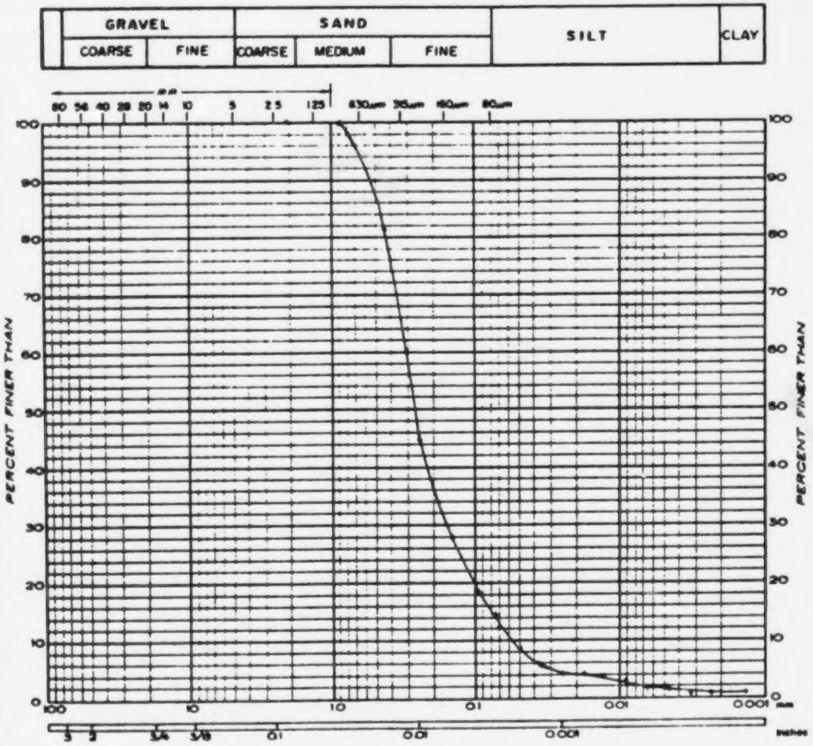
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. GM21 Sample No. 6
Depth 5.5m TO 6.1m

DRAWING NO.



TAILINGS

D60: 0.32 D30: 0.16 D10: 0.06

REMARKS SAND - damp, medium dense, poorly graded, fine, reddish brown.

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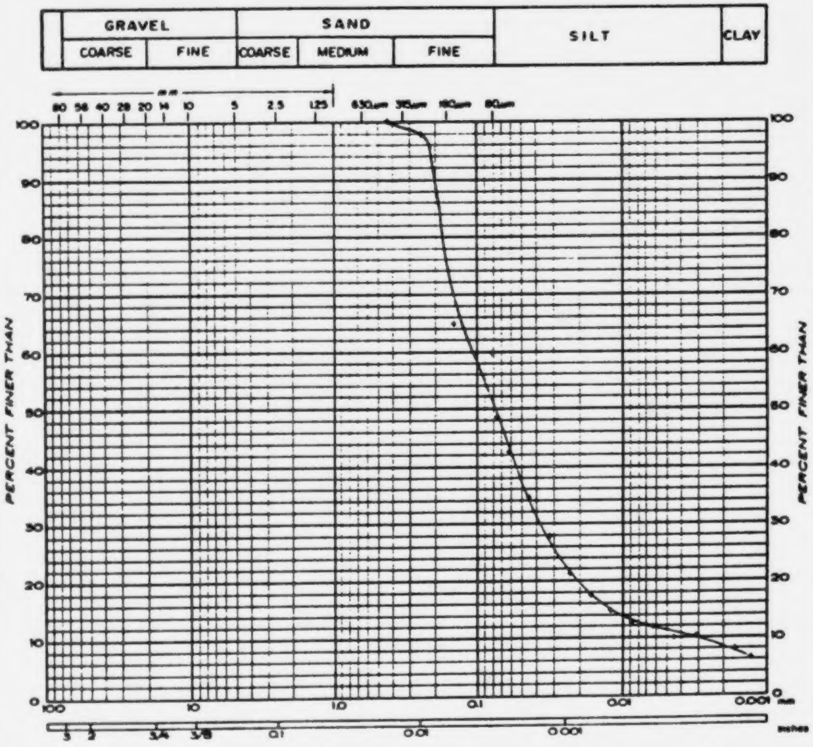
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No SM3A Sample No 1
Depth 0.0

DRAWING NO



TAILINGS

D60: 0.10 D30: 0.035 D10: 0.003

REMARKS SILT - sandy, damp, medium dense, poorly graded, fine, reddish brown.

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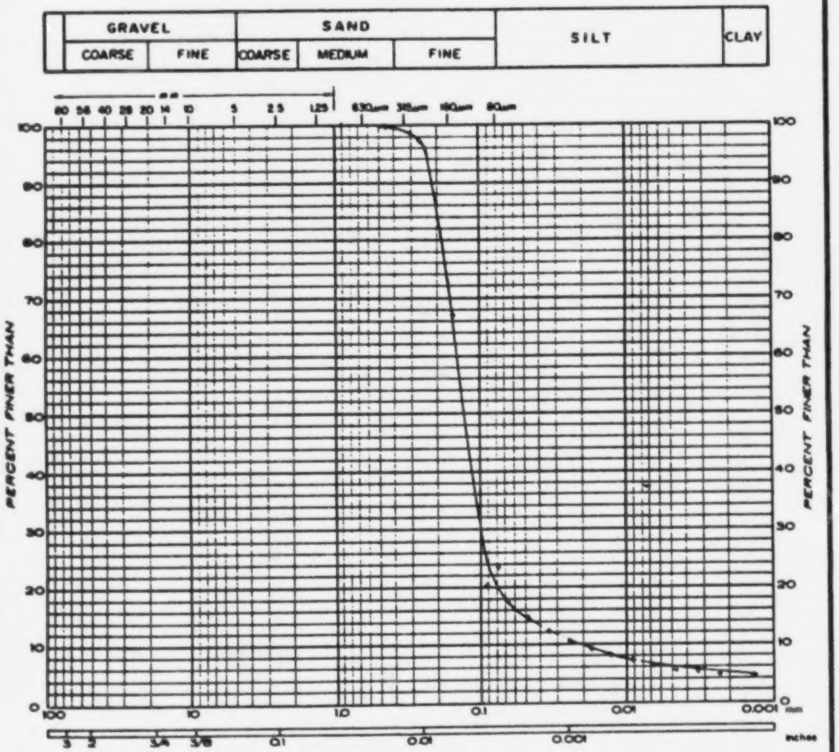
NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No GM3A Sample No 3
Depth 2.4m TO 3.0m

DRAWING NO.



TAILINGS

D_{60}: 0.14 D_{30}: 0.10 D_{10}: 0.023

REMARKS SAND - damp, dense, poorly graded, fine, reddish brown

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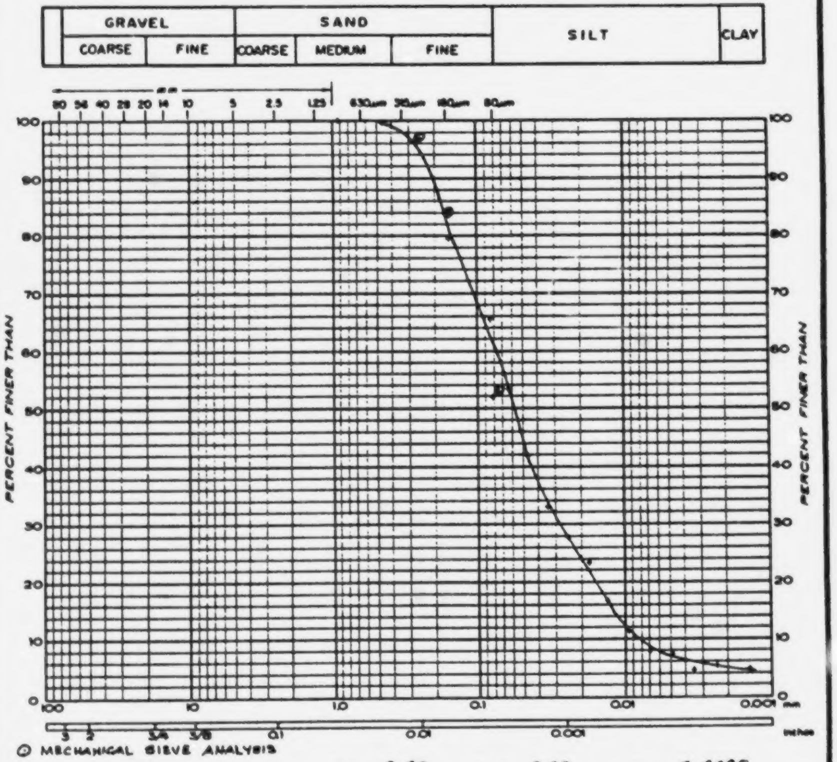
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No GM3A. Sample No: 4
Depth 3.7m

DRAWING NO.



TAILINGS

D_{60}: 0.08 D_{30}: 0.03 D_{10}: 0.0085

REMARKS SILT - very sandy, moist, stiff, non plastic, reddish brown.

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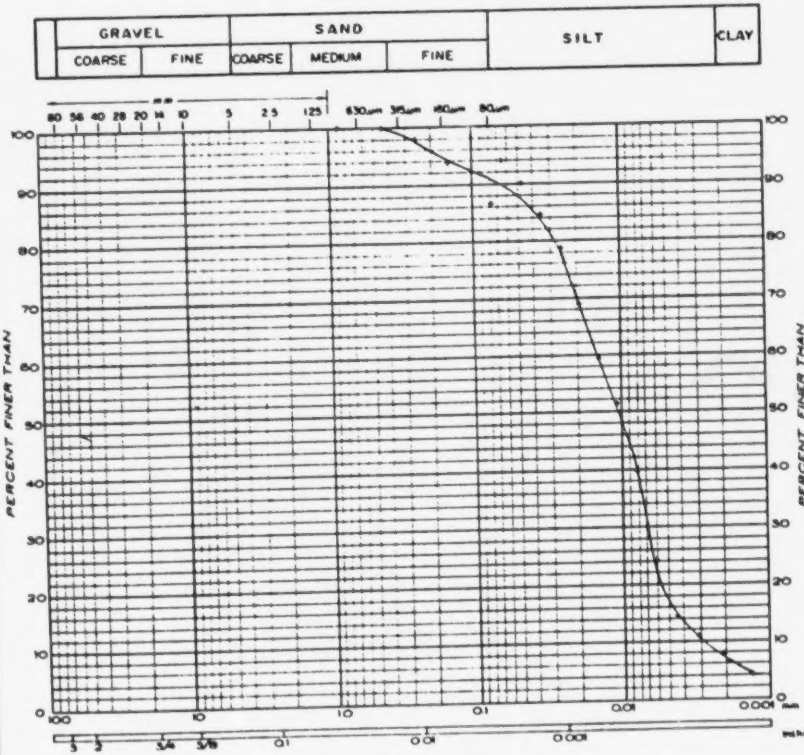
GRAIN SIZE DISTRIBUTION

Test Hole No GM3A. Sample No: 8
Depth 8.4m

DRAWING NO.



TAILINGS

D60 : 0.015 D30 : 0.0065 D10 : 0.0028

REMARKS SILT - wet, firm, low plastic, reddish brown, trace of sand, trace of clay.

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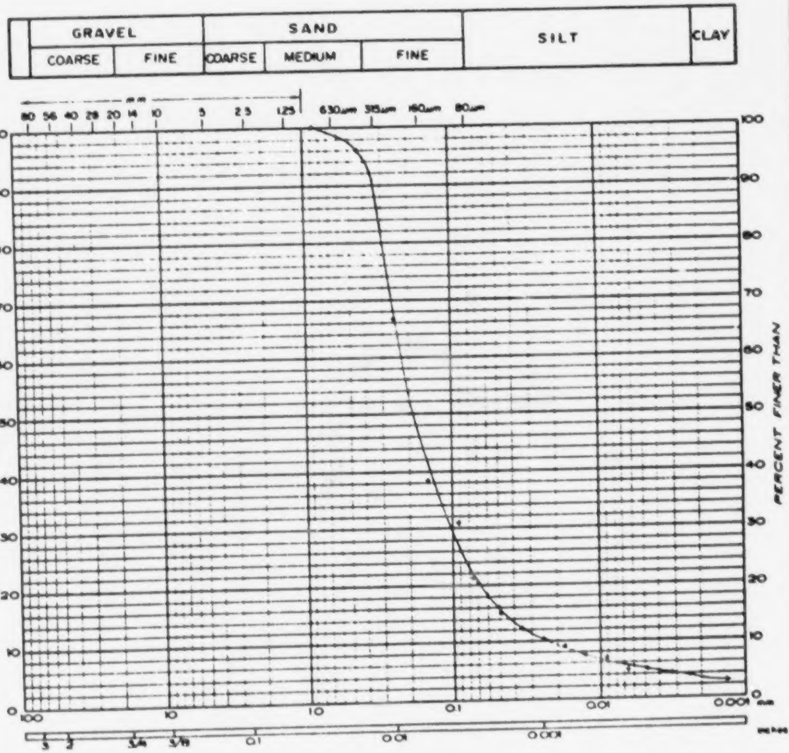
NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. GM4A Sample No. 2
Depth 0.0 TO 0.1m

DRAWING NO.



TAILINGS

D60 : 0.23 D30 : 0.095 D10 : 0.023

REMARKS SAND - moist, loose, pooly graded, fine size, reddish brown, silty.

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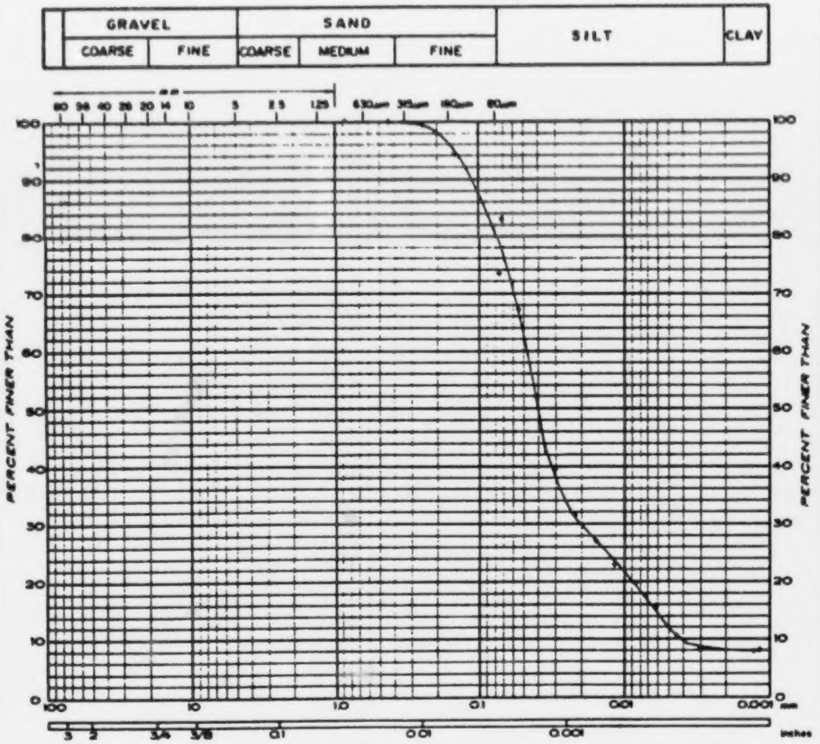
NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. GM5A Sample No. 1
Depth 0.0

DRAWING NO.



TAILINGS

D_{60}: 0.046 D_{30}: 0.020 D_{10}: 0.0041

REMARKS SILT, saturated, low to non plastic, reddish brown, sandy

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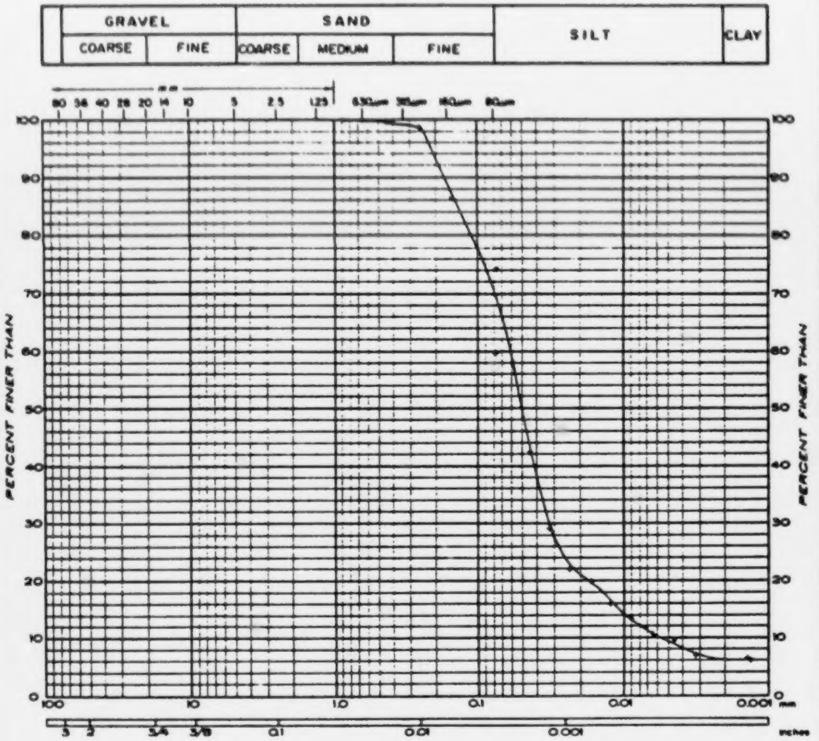
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. GM 6d Sample No: 4
Depth 4.2m TO 4.3m

DRAWING NO.



TAILINGS

D_{60}: 0.06 D_{30}: 0.033 D_{10}: 0.006

REMARKS SILT - saturated, low to non plastic, reddish brown, sandy

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NATIONAL URANIUM TAILINGS PROGRAM
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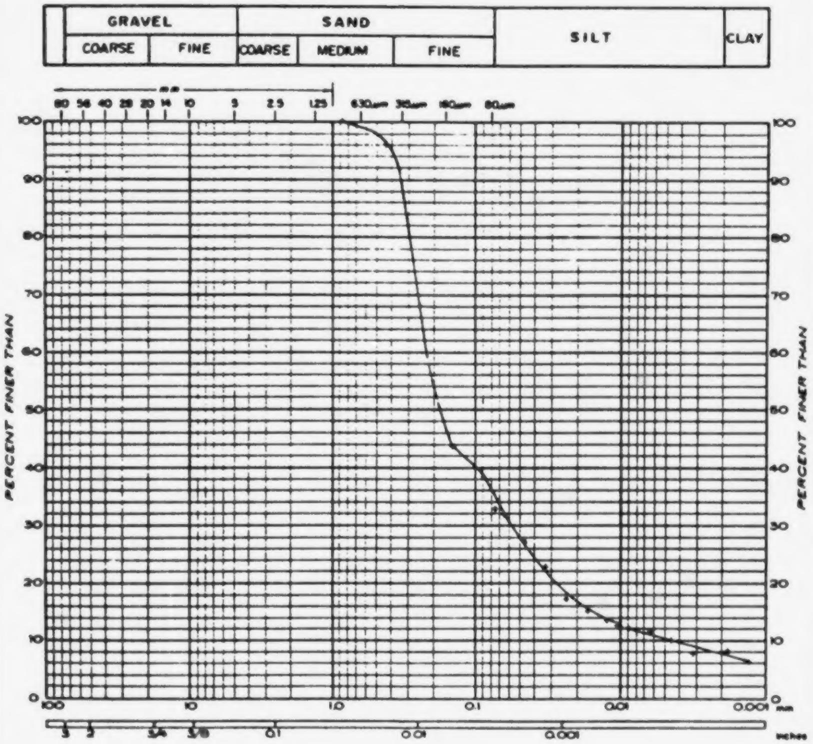
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. GM 6d Sample No: 5
Depth: 7.6m TO 7.8m

DRAWING NO.



TAILINGS

D_{60}: 0.22 D_{30}: 0.058 D_{10}: 0.0045

REMARKS SAND: moist, poorly graded, fine, reddish brown, silty, odor...

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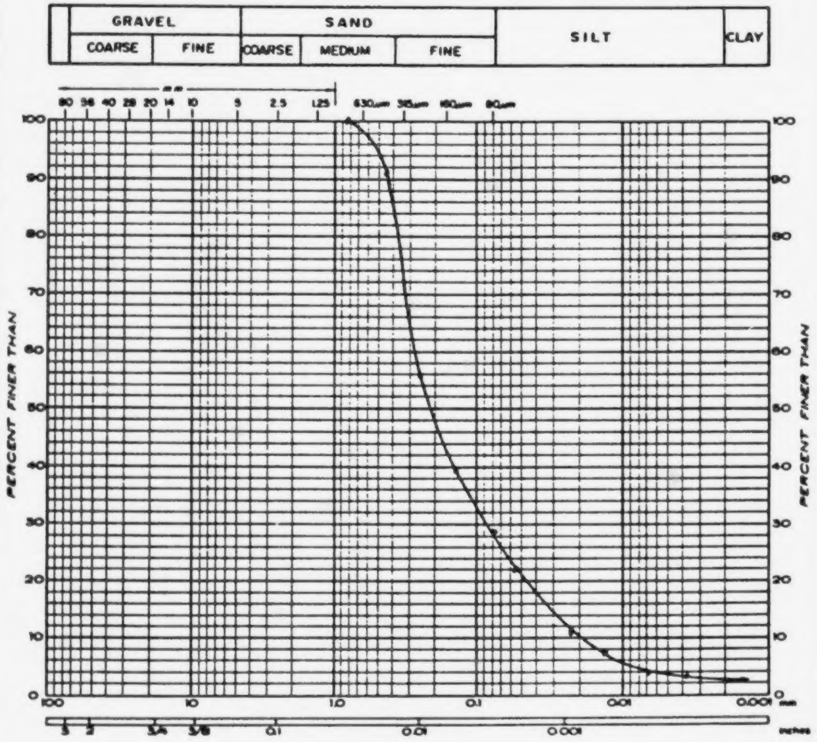
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. GM.7A Sample No. 1
Depth 0

DRAWING NO.



TAILINGS

D_{60}: 0.28 D_{30}: 0.09 D_{10}: 0.02

REMARKS SAND: damp, poorly graded, fine, reddish brown, few fibres...

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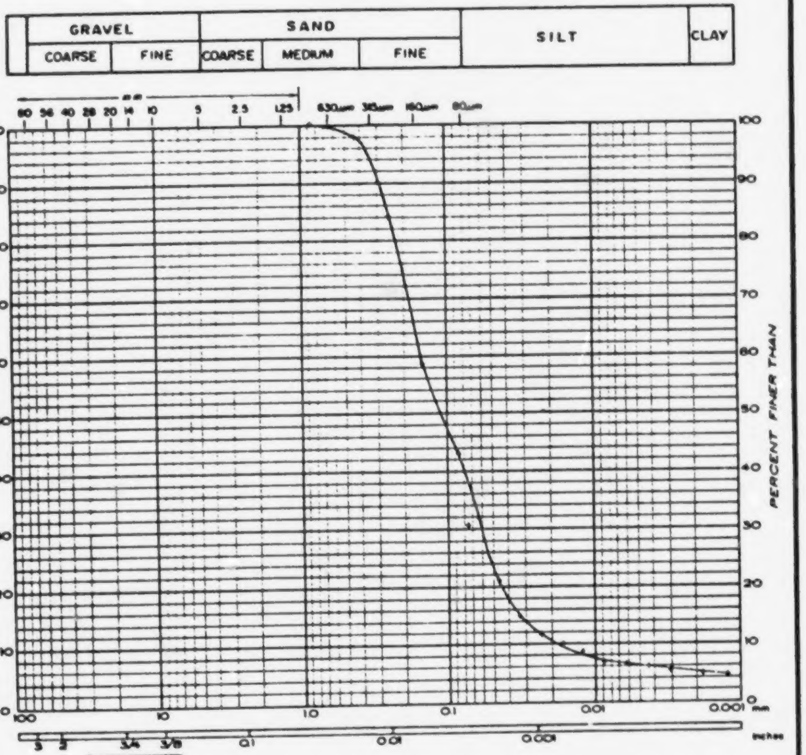
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. GM.8A Sample No. 1
Depth SURFACE

DRAWING NO.



TAILINGS

D_{60}: 0.15 D_{30}: 0.060 D_{10}: 0.017

IN LABORATORY CHECK:

REMARKS SAND - damp, poorly graded, fine, reddish brown, few fibres

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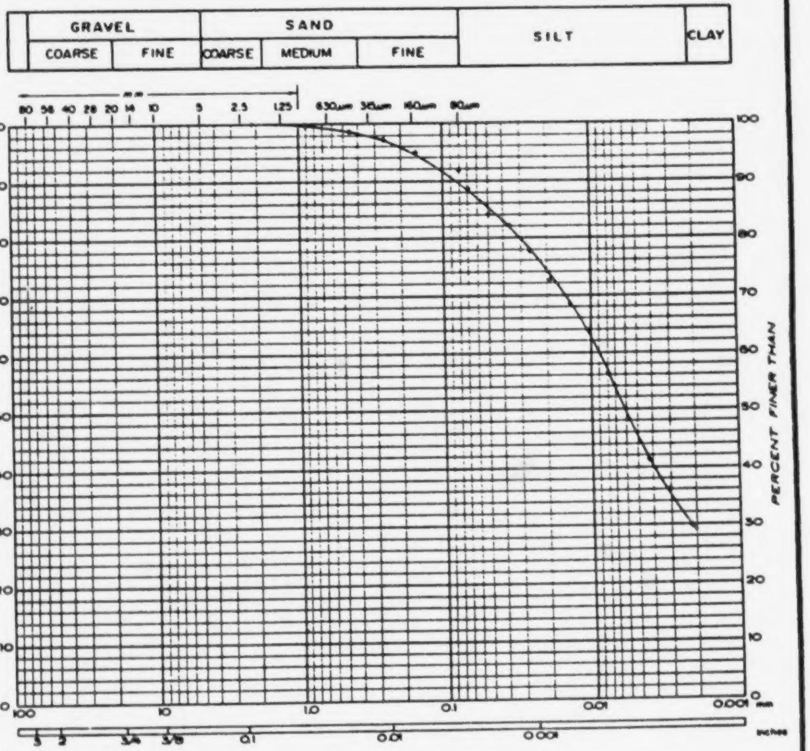
GRAIN SIZE DISTRIBUTION

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

Test Hole No GM.84 Sample No 1
Depth 0

DRAWING NO.



TAILINGS

D_{60}: 0.0087 D_{30}: 0.0023 D_{10}: –

REMARKS SILT, - wet, non plastic, reddish brown

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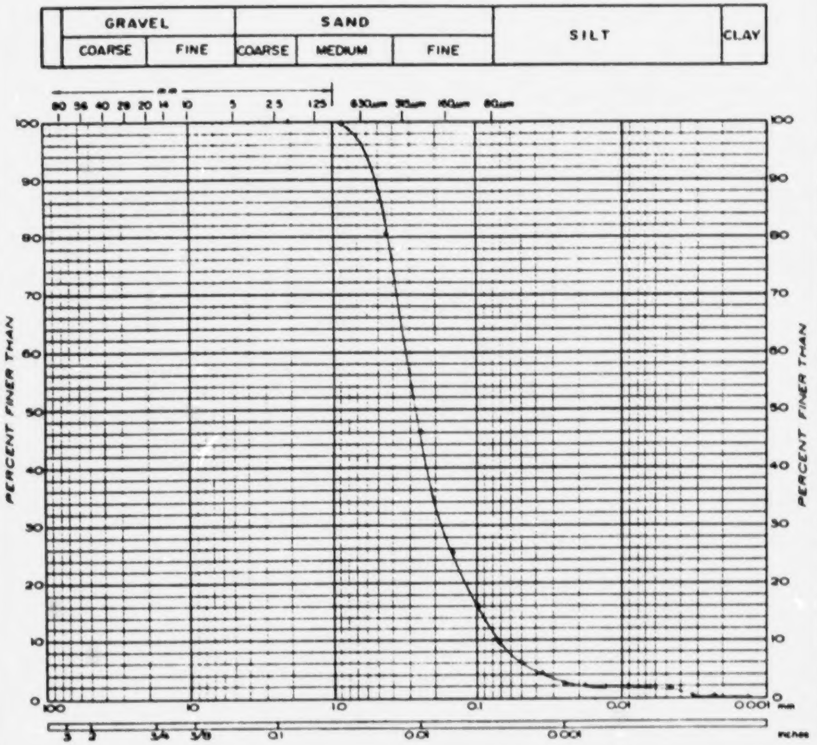
GRAIN SIZE DISTRIBUTION

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

Test Hole No: GM94 Sample No: 3
Depth: 4.1m

DRAWING NO.



TAILINGS

D_{60}: 0.30 D_{30}: 0.19 D_{10}: 0.073

REMARKS SAND- damp, poorly graded, fine, reddish brown

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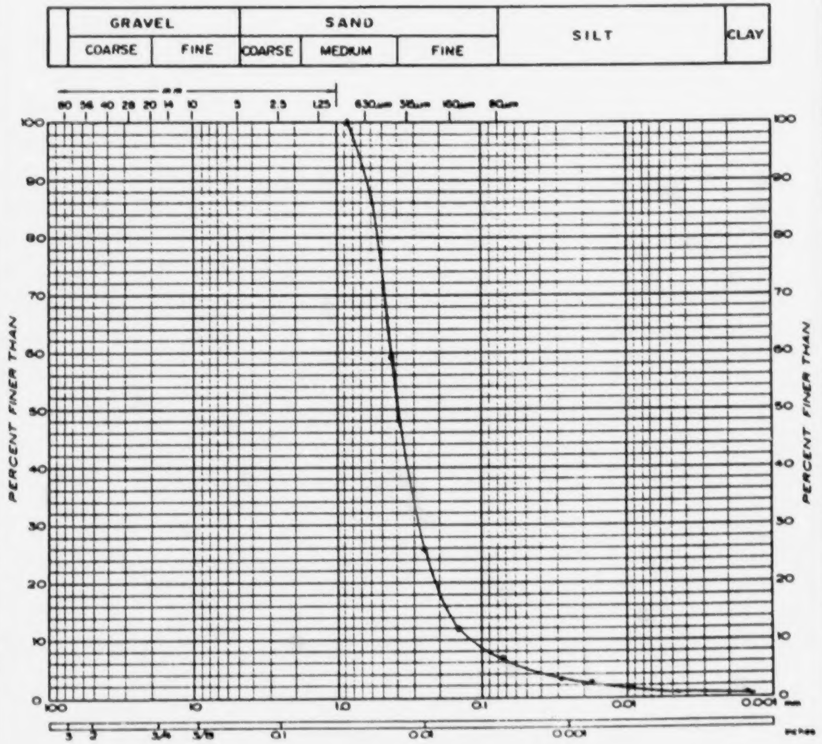
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No GH 34 Sample No 1
Depth 2

DRAWING NO



TAILINGS

D_{60}: 0.44 D_{30}: 0.28 D_{10}: 0.12

REMARKS SAND: damp, poorly graded, fine to medium size, reddish brown

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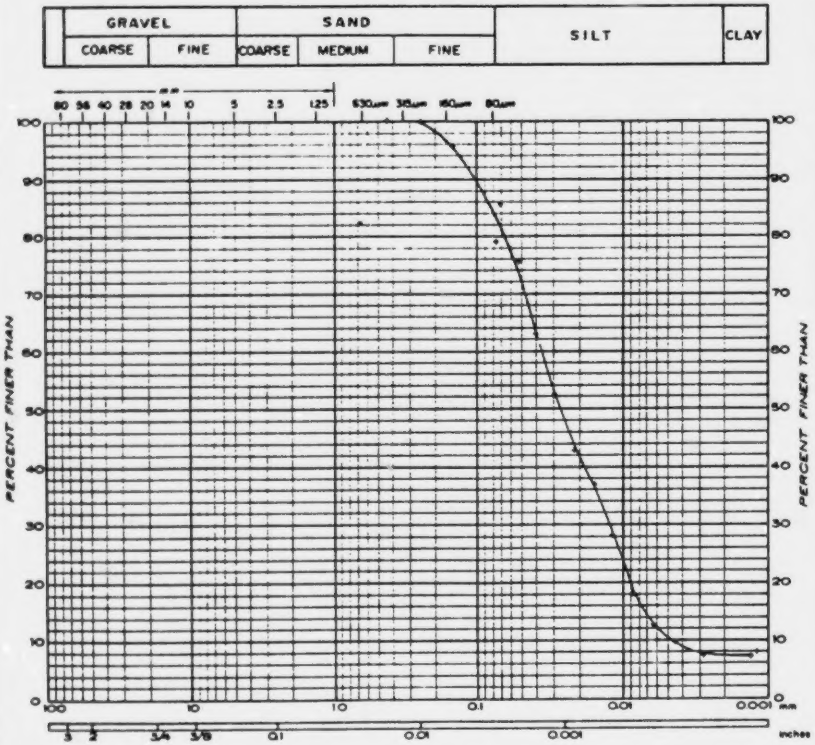
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No GH14 Sample No S1
Depth SURFACE

DRAWING NO



TAILINGS

D_{60}: 0.036 D_{30}: 0.013 D_{10}: 0.0045

REMARKS SILT- saturated, very stiff, low plastic, reddish brown, trace of sand, trace of clay.

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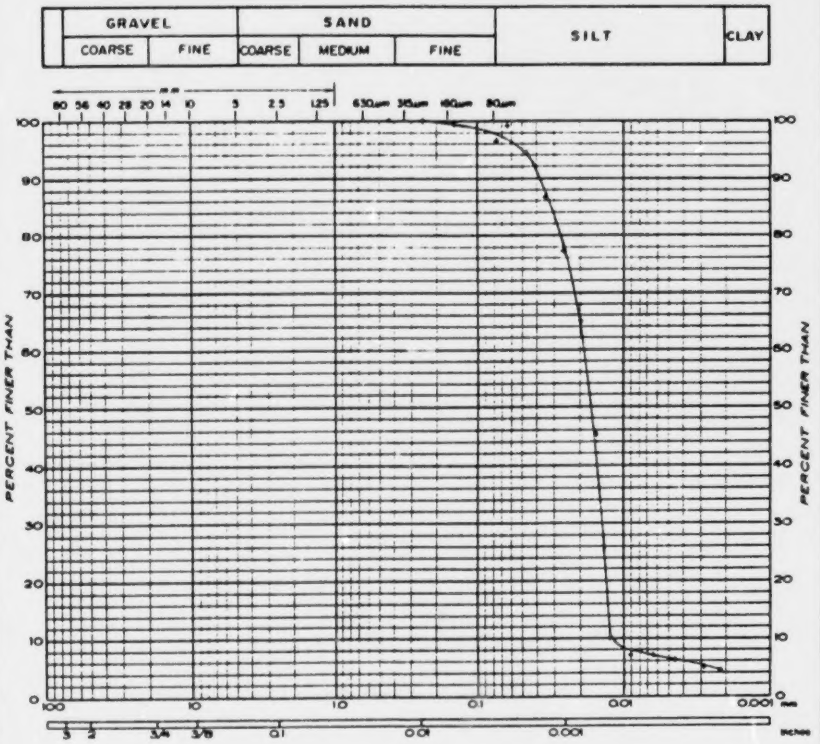
GRAIN SIZE DISTRIBUTION

Test Hole No GM/2A Sample No: 2
Depth: 1.2m TO 1.4m

DRAWING NO.



TAILINGS

D_{60}: 0.019 D_{30}: 0.014 D_{10}: 0.012

REMARKS SILT- low plastic, very stiff, reddish brown, trace of fine sand.

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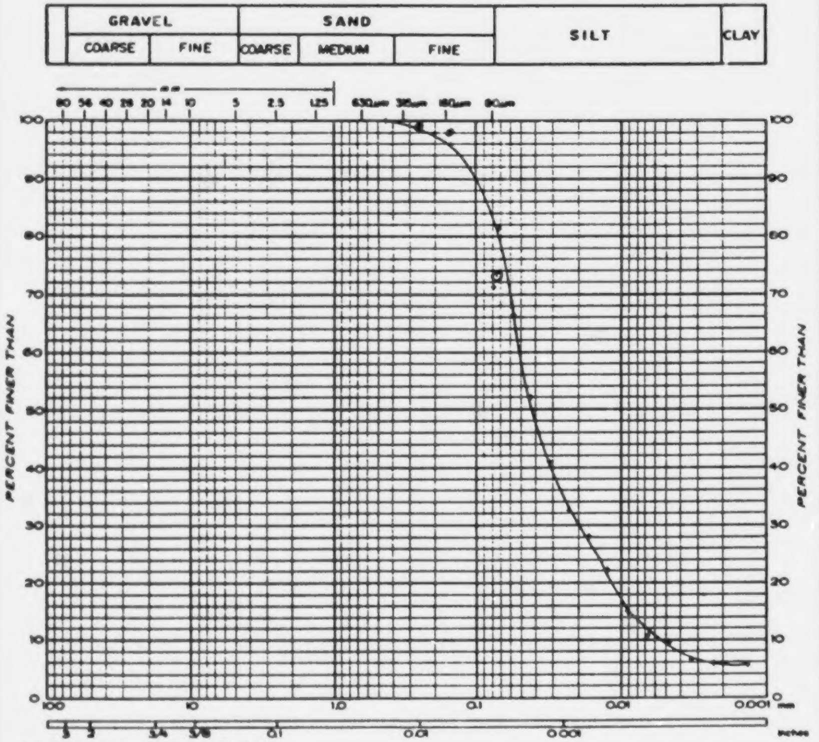
GRAIN SIZE DISTRIBUTION

Test Hole No GM/3A Sample No: 1
Depth 0

DRAWING NO.



⊙ MECHANICAL SIEVE ANALYSIS.

D₆₀: 0.040 D₃₀: 0.020 D₁₀: 0.0035

TAILINGS

REMARKS SILT - saturated, low plastic, firm, reddish brown

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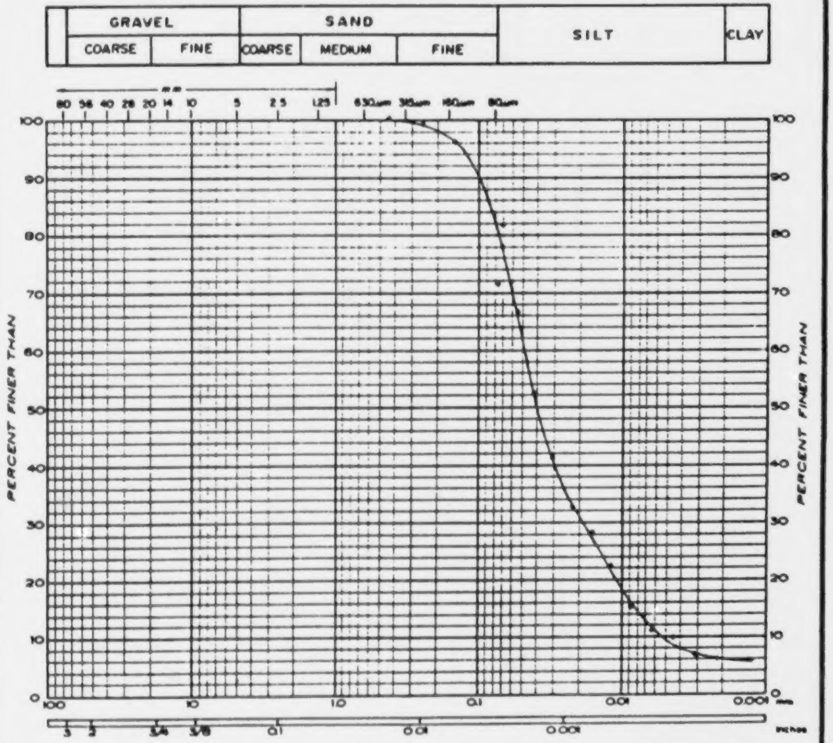
GRAIN SIZE DISTRIBUTION

Test Hole No GM13A Sample No 2
Depth 1.8m

DRAWING NO.



TAILINGS

D₆₀: 0.048 D₃₀: 0.020 D₁₀: 0.0055

IN LABORATORY CHECK:

REMARKS SILT - saturated, low plastic, firm, reddish brown

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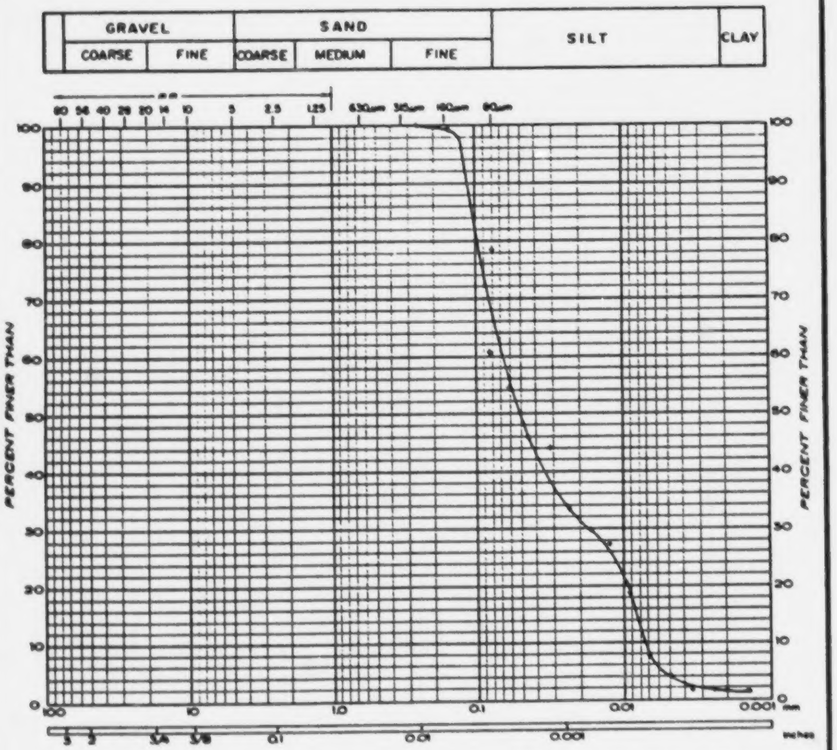
GRAIN SIZE DISTRIBUTION

Test Hole No GM13A Sample No 2
Depth 1.8m

DRAWING NO. <



TAILINGS

D60: 0.067 D30: 0.018 D10: 0.007

REMARKS SILT - wet, low plastic, stiff, reddish brown

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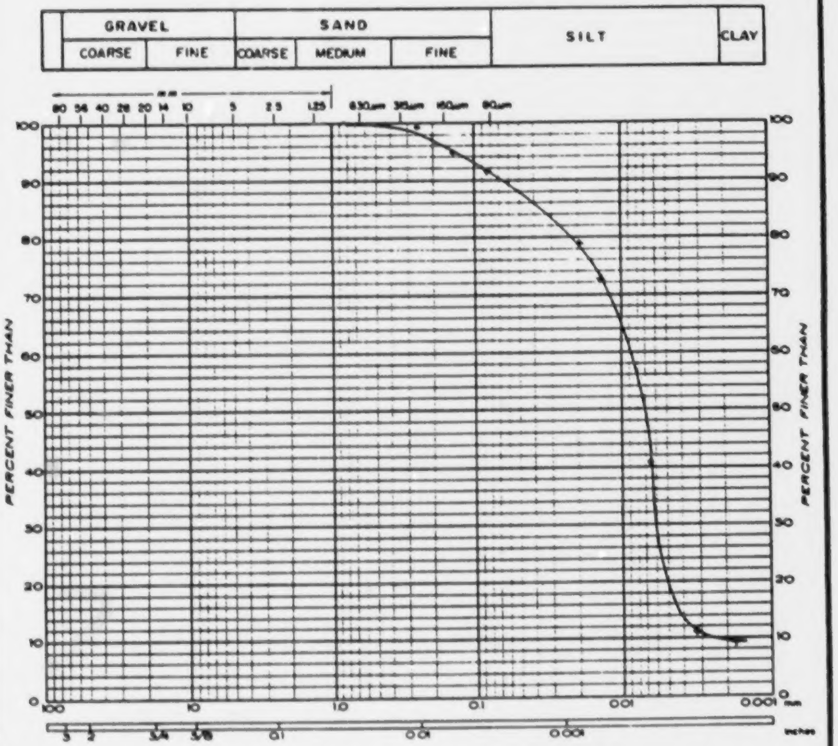
GRAIN SIZE DISTRIBUTION

Test Hole No. GM13A Sample No: 5
Depth 3.0m

DRAWING NO.



TAILINGS

D60: 0.009 D30: 0.004 D10: 0.0012

REMARKS SILT - wet, low plastic, stiff, reddish brown

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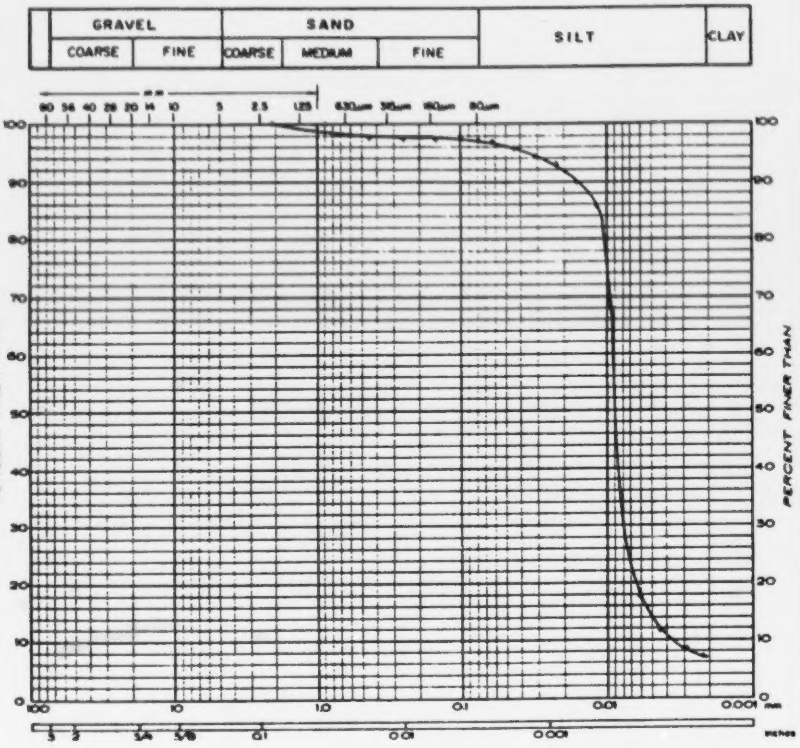
GRAIN SIZE DISTRIBUTION

Test Hole No GM13A Sample No 55
Depth 6.1m to 6.6m

DRAWING NO.



NATIVE SOIL

D_{60}: 0.009 D_{30}: 0.008 D_{10}: 0.003

REMARKS SILT - reddish brown with clayey lenses.

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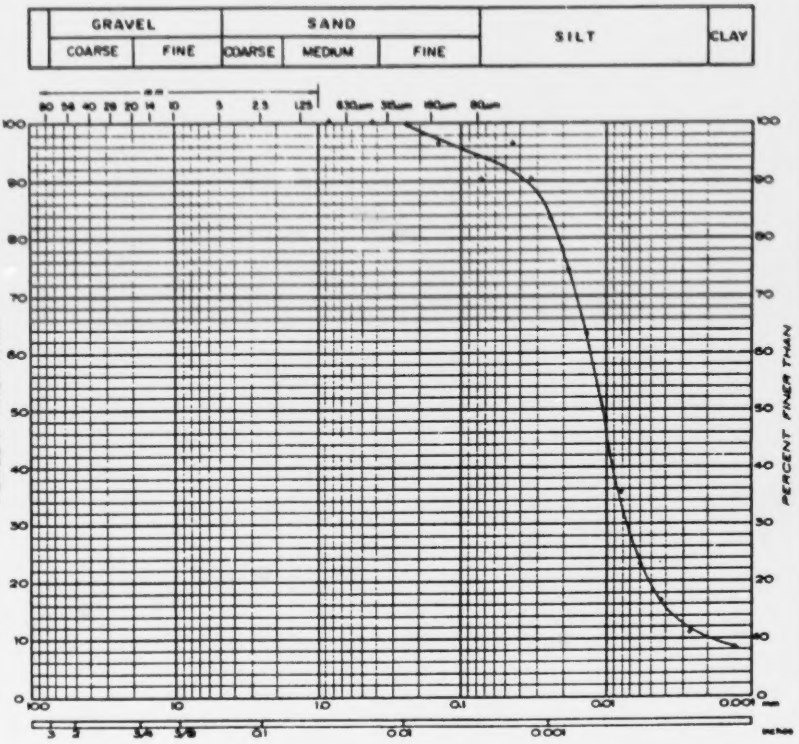
GRAIN SIZE DISTRIBUTION

Test Hole No GM/3A Sample No 6
Depth 7.6 m

DRAWING NO.



TAILINGS

D_{60}: 0.012 D_{30}: 0.007 D_{10}: 0.0023

REMARKS SILT - frozen, non plastic, reddish brown.

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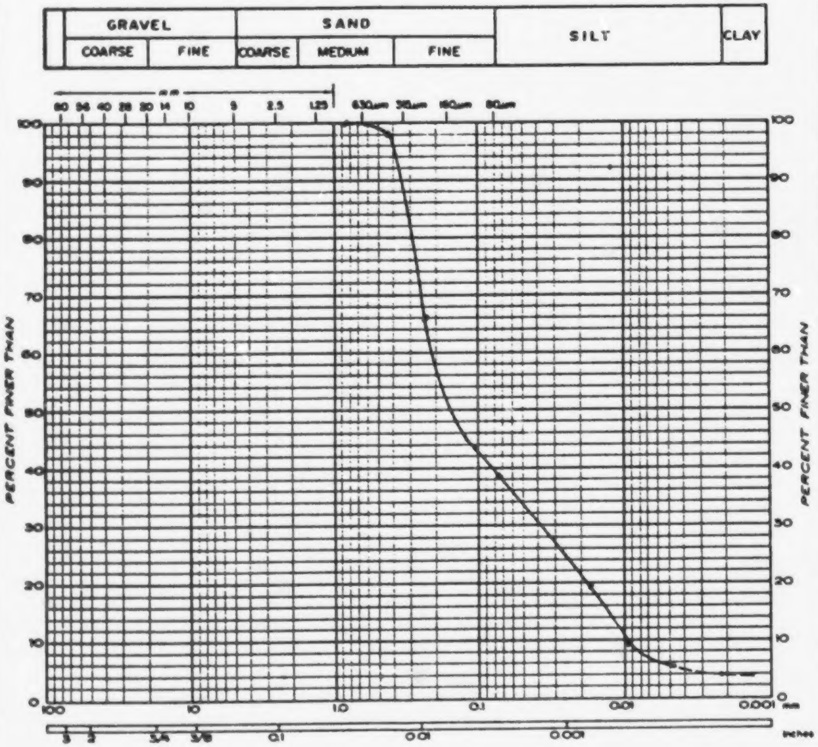
GRAIN SIZE DISTRIBUTION

Test Hole No GM/7A Sample No 6
Depth 0.0 To 0.1m

DRAWING NO.



TAILINGS

D_{60}: 0.21 D_{30}: 0.040 D_{10}: 0.0095

REMARKS SAND: moist, poorly graded, fine, reddish brown

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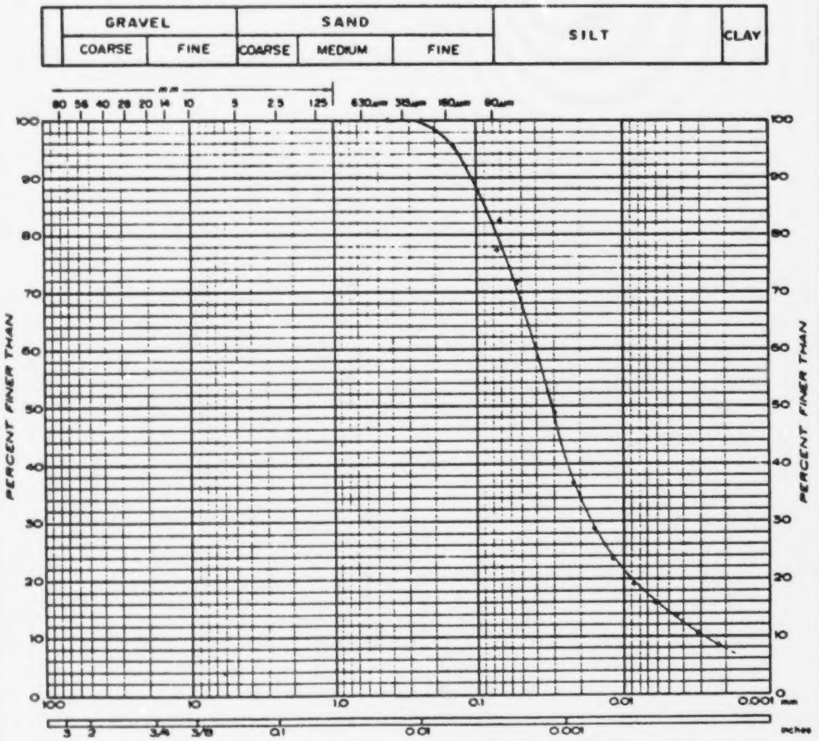
GRAIN SIZE DISTRIBUTION

Test Hole No. GM/81 Sample No: 1
Depth SURFACE

DRAWING NO.



TAILINGS

D_{60}: 0.04 D_{30}: 0.017 D_{10}: 0.003

REMARKS SILT - frozen to 1.0m, low plastic, reddish brown, trace of clay

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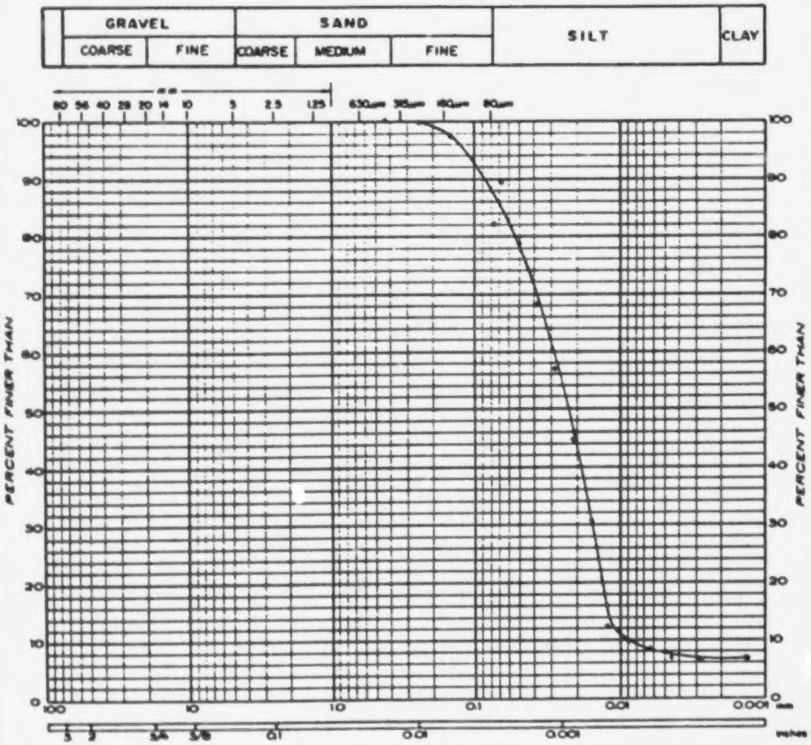
GRAIN SIZE DISTRIBUTION

Test Hole No. GM/94 Sample No: 3
Depth 0.0 TO 0.1m

DRAWING NO.



TAILINGS

D_{60}: 0.031 D_{30}: 0.015 D_{10}: 0.009

REMARKS SILT - saturated, soft, non plastic, reddish brown

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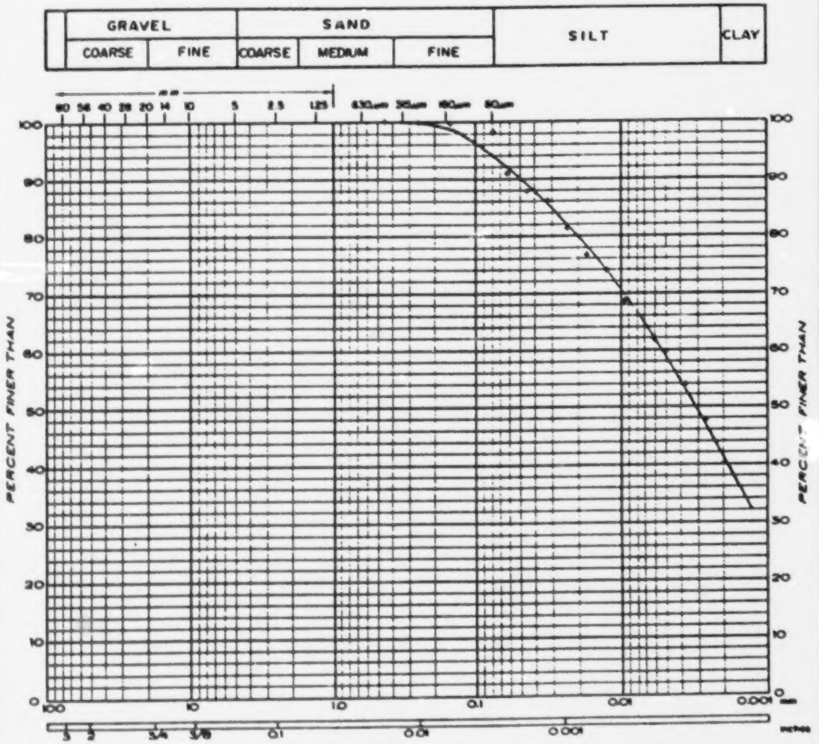
GRAIN SIZE DISTRIBUTION

Test Hole No GC5A Sample No 1
Depth 1.5m TO 1.8m

DRAWING NO.



NATIVE SOIL

D_{60}: 0.0055 D_{30}: 0.0013 D_{10}: < 0.001

REMARKS SILT - very moist, stiff, low plastic, light grey.

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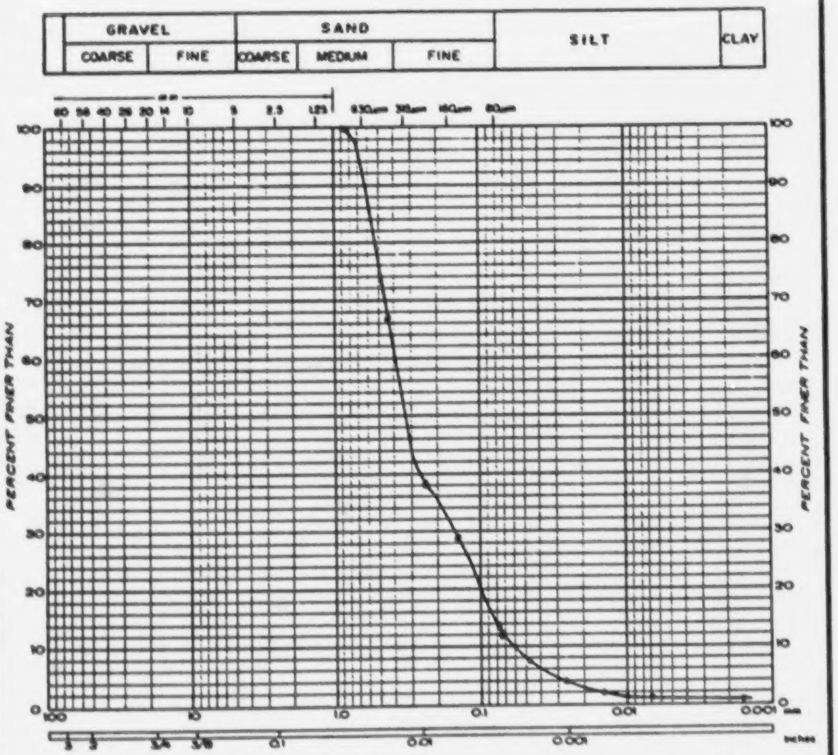
GRAIN SIZE DISTRIBUTION

Test Hole No GC5A Sample No 5
Depth 4.6m

DRAWING NO.



D_{60}: 0.40 D_{30}: 0.15 D_{10}: 0.06

TAILINGS

REMARKS SAMPLE B: (GUNNAR CENTRAL)

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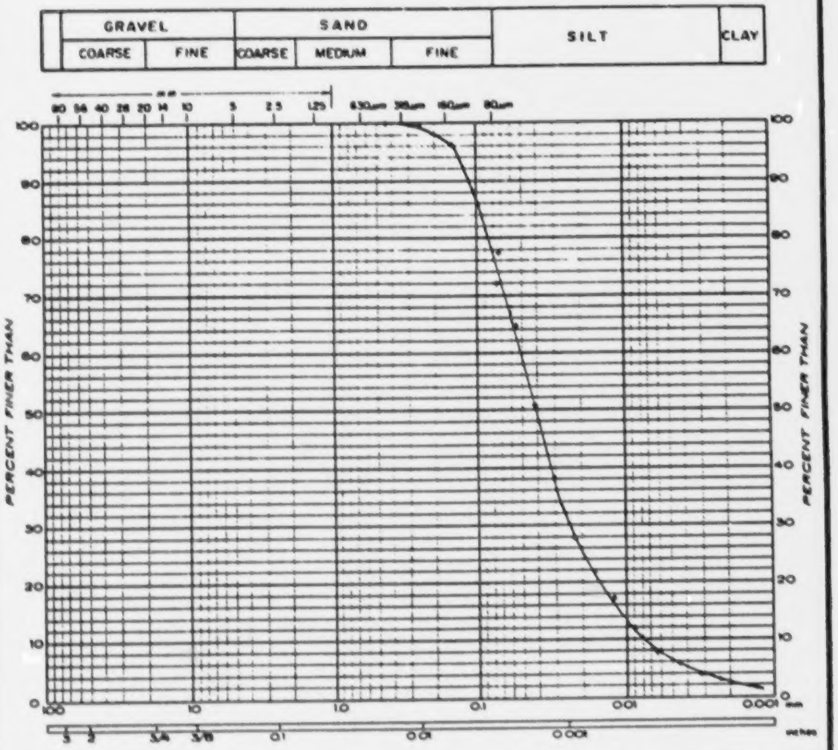
GRAIN SIZE DISTRIBUTION

Test Hole No. GC5A Sample No. 59
Depth

DRAWING NO.



D_{60}: 0.05 D_{30}: 0.024 D_{10}: 0.008

TAILINGS

REMARKS SILT - saturated, soft, low plastic, dark reddish brown.

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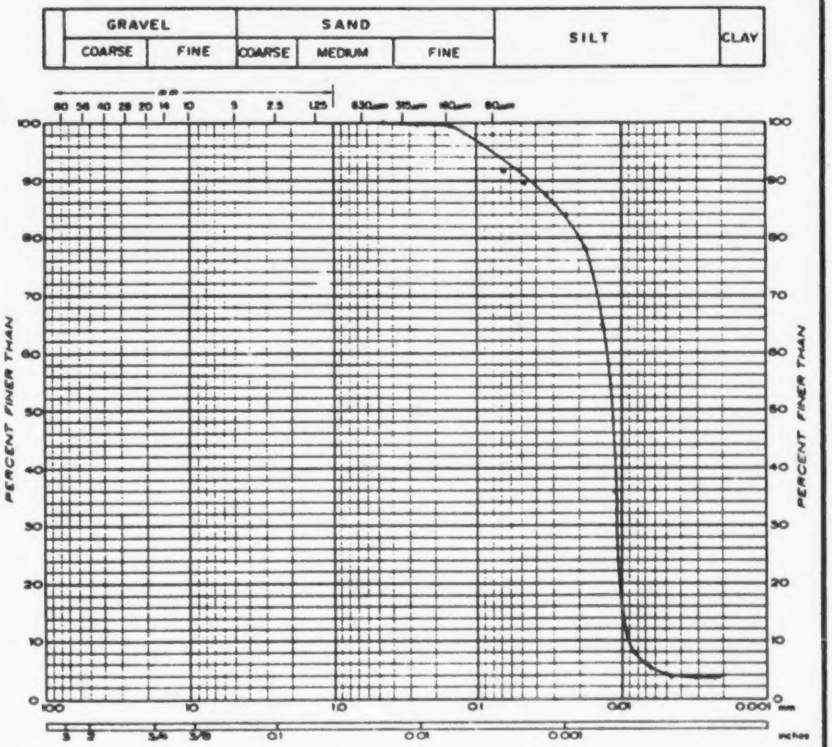
GRAIN SIZE DISTRIBUTION

Test Hole No. LB2A Sample No. 1
Depth 0

DRAWING NO.



TAILINGS

D_{60} : 0.013 D_{30} : 0.0105 D_{10} : 0.009

REMARKS CLAY- saturated, soft, medium plastic, reddish brown, silty, little fine sand

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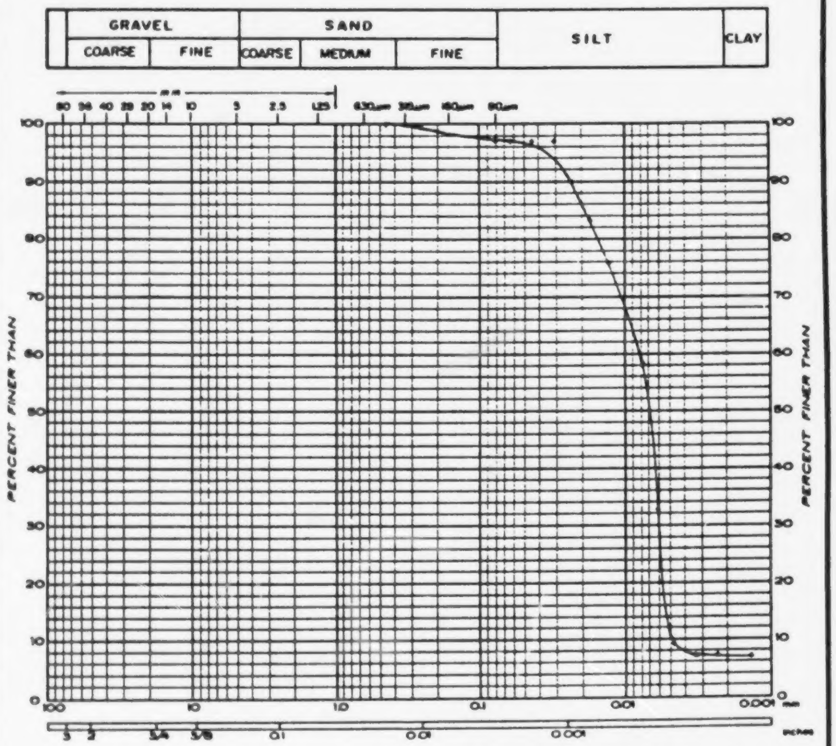
GRAIN SIZE DISTRIBUTION

Test Hole No. LB 2A Sample No. 3
Depth 1.9m

DRAWING NO.



TAILINGS

D_{60} : 0.008 D_{30} : 0.008 D_{10} : 0.005

REMARKS SILT - saturated, soft, low plastic, dark reddish brown.

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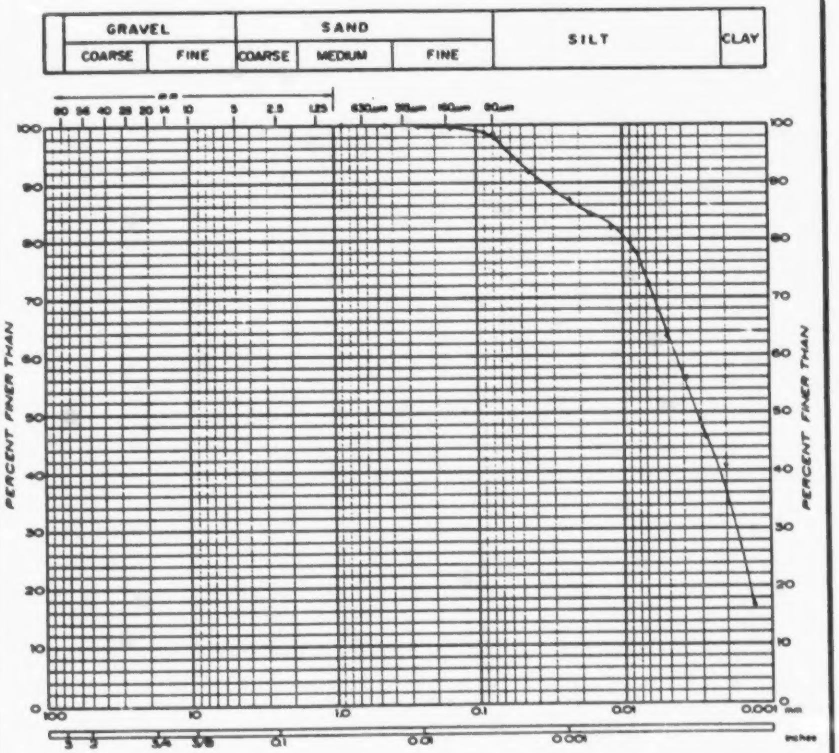
GRAIN SIZE DISTRIBUTION

Test Hole No. LB 2A Sample No. 4
Depth 2.5m To 3.1m

DRAWING NO.



NATIVE SOIL

D_{60}: 0.0044 D_{30}: 0.0017 D_{10}: -

REMARKS ORGANIC SILT: moist, soft, highly plastic, green, odor.

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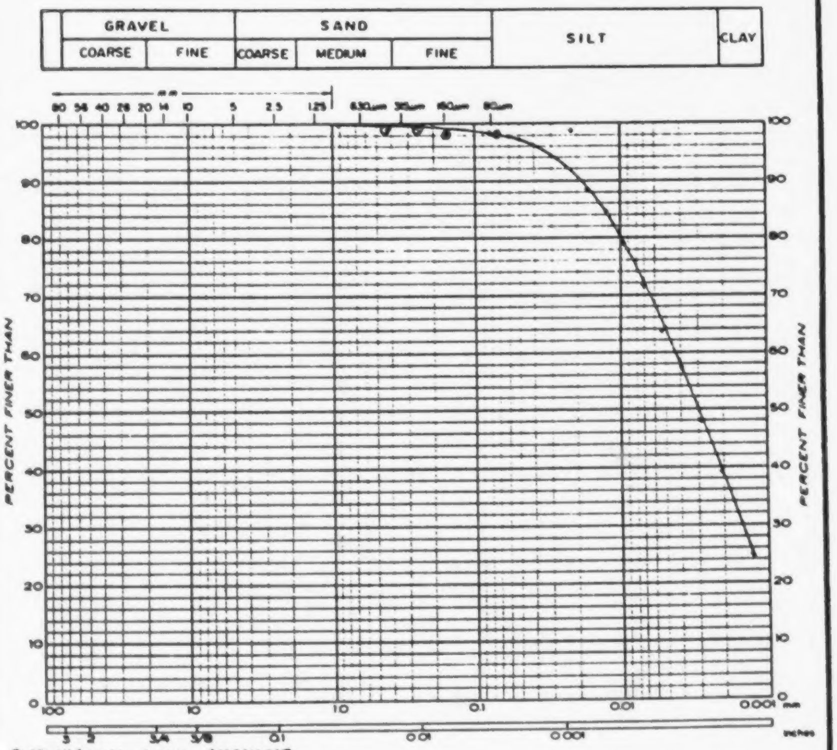
GRAIN SIZE DISTRIBUTION

Test Hole No. LB 2.1 Sample No. 7
Depth 4.6m

DRAWING NO.



○ MECHANICAL SIEVE ANALYSIS

NATIVE SOIL

D_{60}: 0.0045 D_{30}: 0.0015 D_{10}: -

REMARKS CLAY - moist, medium plastic, grey.

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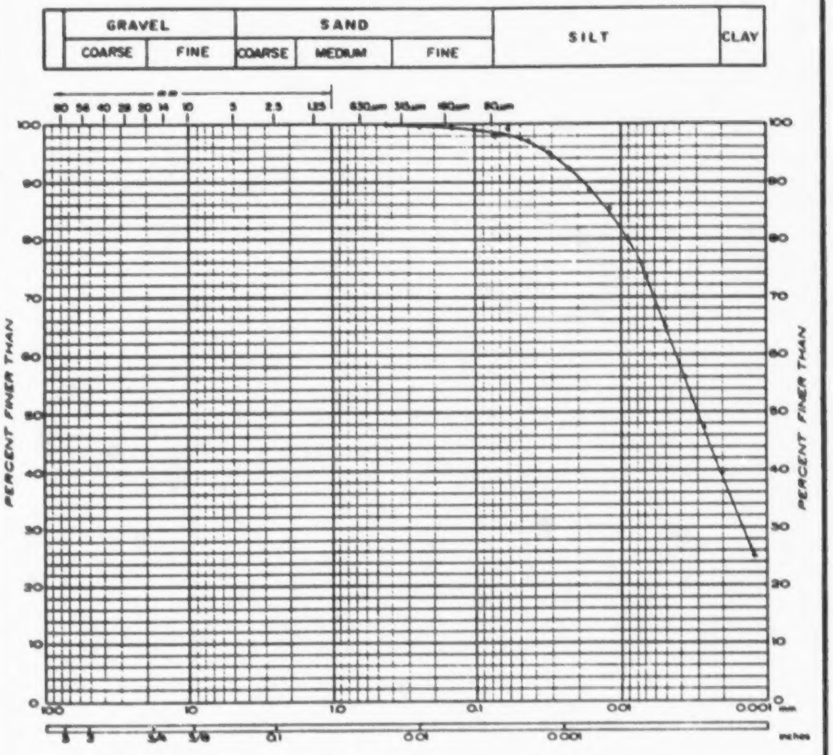
GRAIN SIZE DISTRIBUTION

Test Hole No. LB 2.1 Sample No. 11
Depth 19.2

DRAWING NO.



NATIVE SOIL

D_{60}: 0.0042 D_{30}: 0.0014 D_{10}: -

IN LABORATORY CHECK:

REMARKS CLAY - moist, medium plastic, grey

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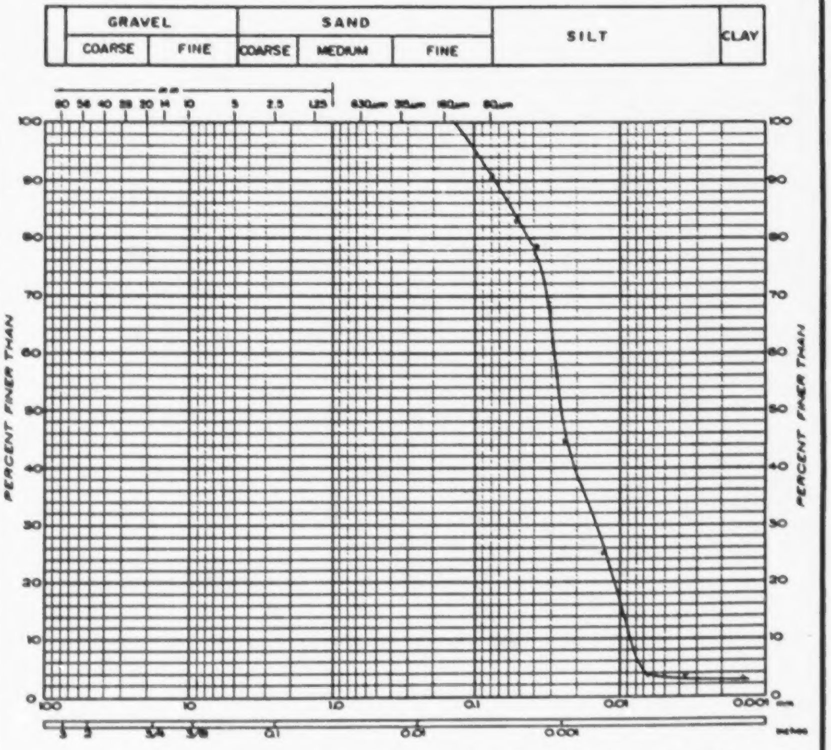
GRAIN SIZE DISTRIBUTION

Test Hole No. 4B 2A Sample No. 11
Depth 19.2

DRAWING NO



TAILINGS

D_{60}: 0.029 D_{30}: 0.014 D_{10}: 0.0085

REMARKS SILT - saturated, firm, non plastic, reddish brown

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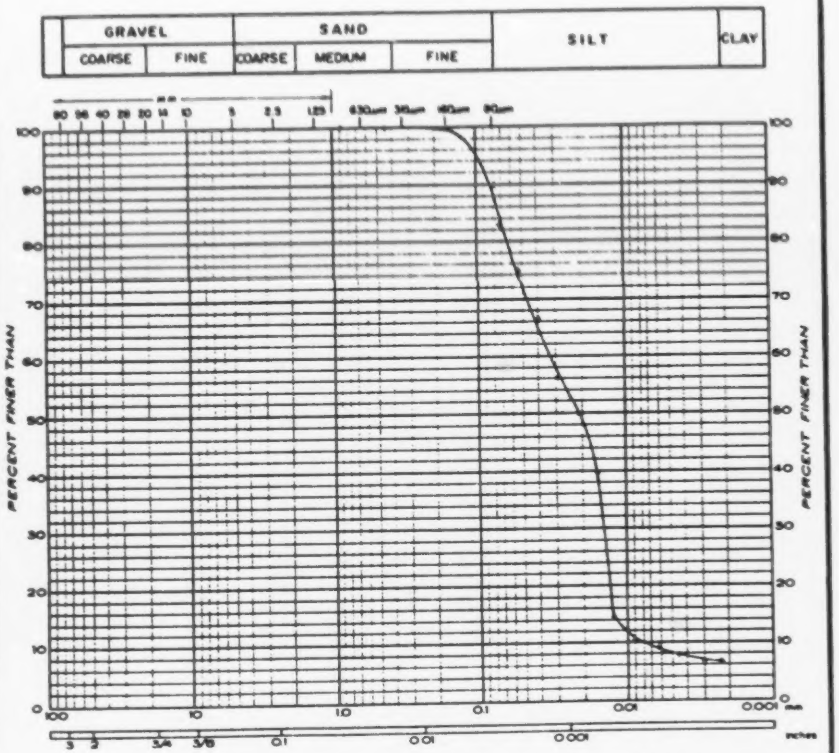
GRAIN SIZE DISTRIBUTION

Test Hole No. 4B7A Sample No. 2
Depth 1.8 m

DRAWING NO.



NATIVE SOIL

D_{60}: 0.032 D_{30}: 0.014 D_{10}: 0.008

REMARKS ORGANIC SILT, damp, stiff, highly plastic, grey-green

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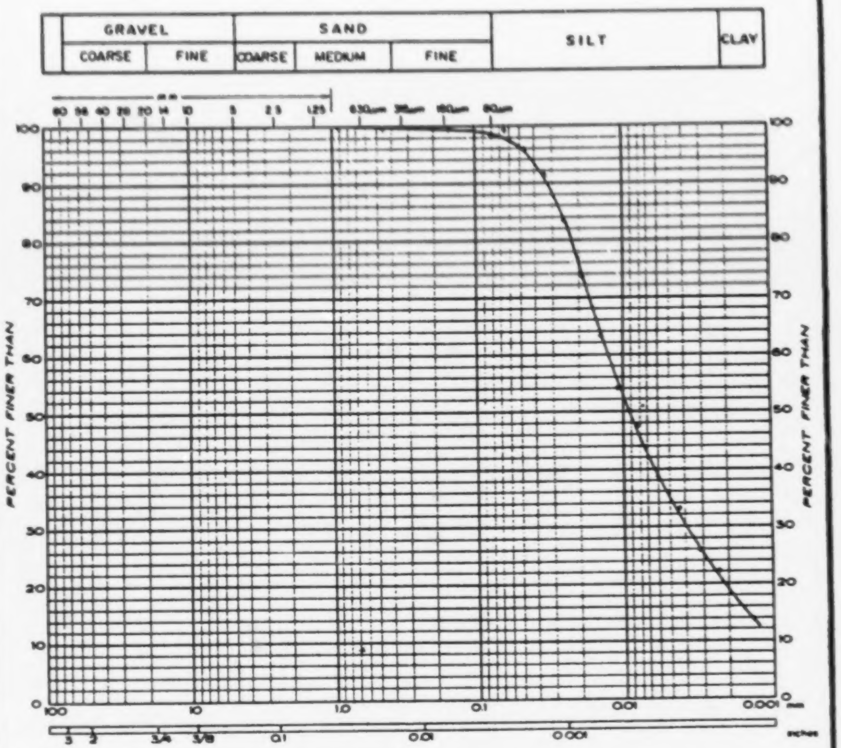
GRAIN SIZE DISTRIBUTION

Test Hole No LB.7A Sample No 5
Depth 3.1m

DRAWING NO



NATIVE SOIL

D_{60}: 0.013 D_{30}: 0.004 D_{10}: -

REMARKS

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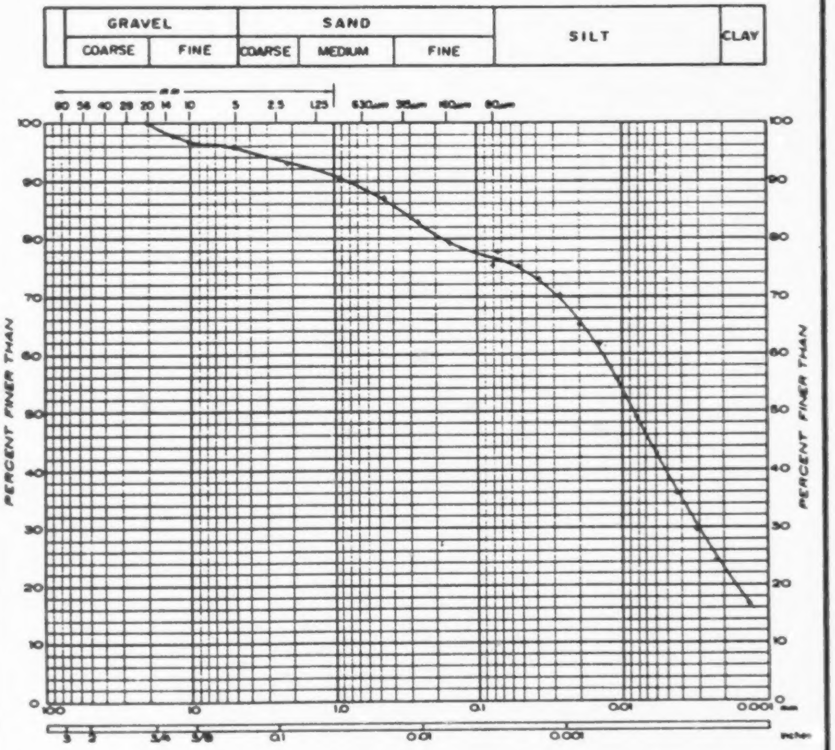
GRAIN SIZE DISTRIBUTION

Test Hole No WR3 Sample No 1
Depth

DRAWING NO.



NATIVE SOIL

D₆₀: 0.014 D₃₀: 0.0032 D₁₀: ....

REMARKS ....

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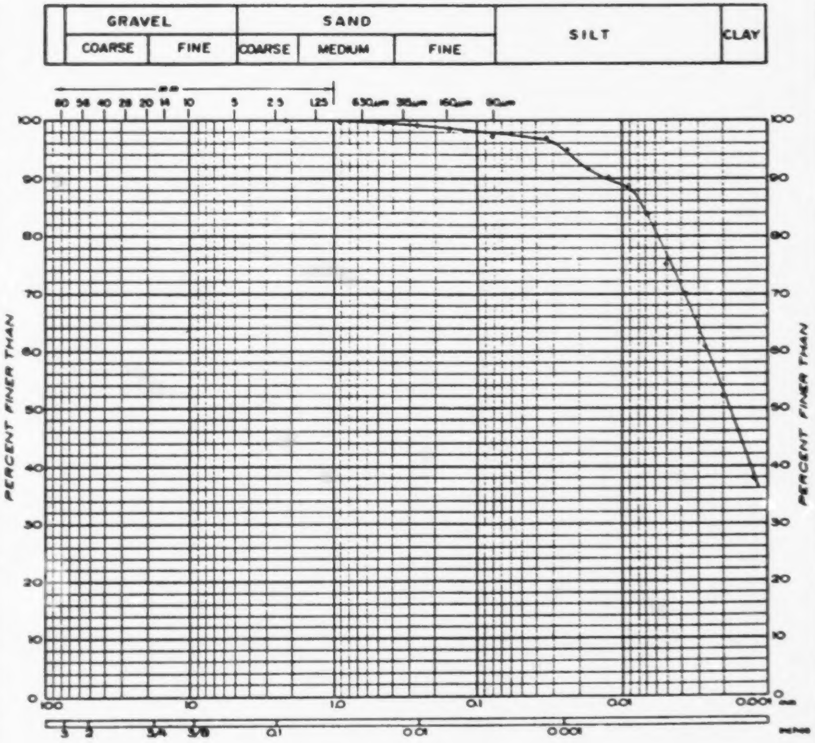
GRAIN SIZE DISTRIBUTION

Test Hole No. WR4 Sample No. 1
Depth ....
DRAWING NO.



NATIVE SOIL

D₆₀: 0.0025 D₃₀: – D₁₀: –

REMARKS ....

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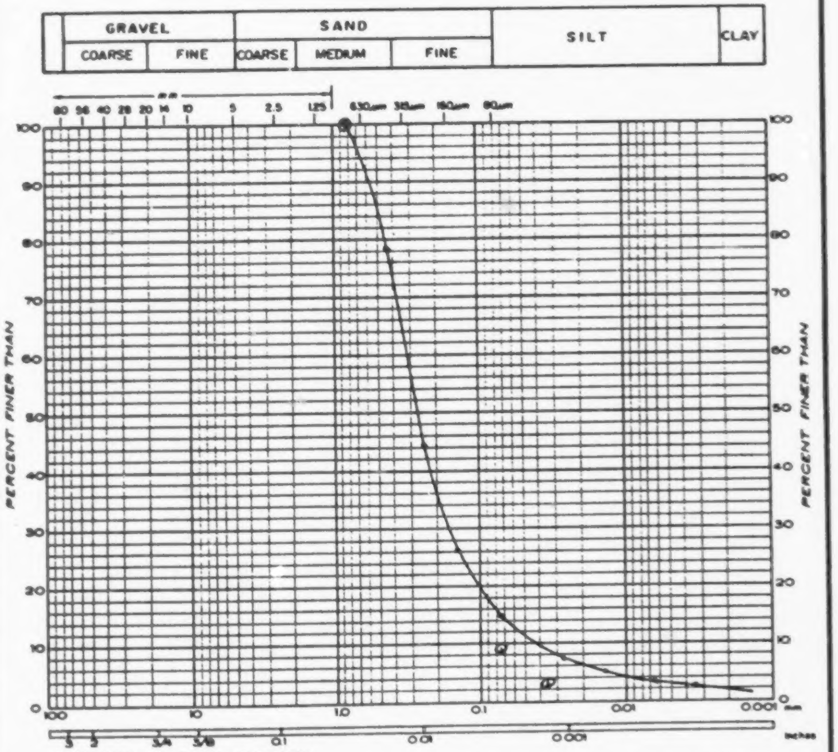
GRAIN SIZE DISTRIBUTION

Test Hole No. WR5 Sample No. 1
Depth ....
DRAWING NO.



○ MECHANICAL SIEVE ANALYSIS

D60: 0.31 D30: 0.17 D10: 0.041

SAMPLE A: (EAST MAIN TAILINGS)
REMARKS COMBINED SAMPLE - GM2A (S1), GM3A (S1), GM10A (S1),
N.I.E (S1)

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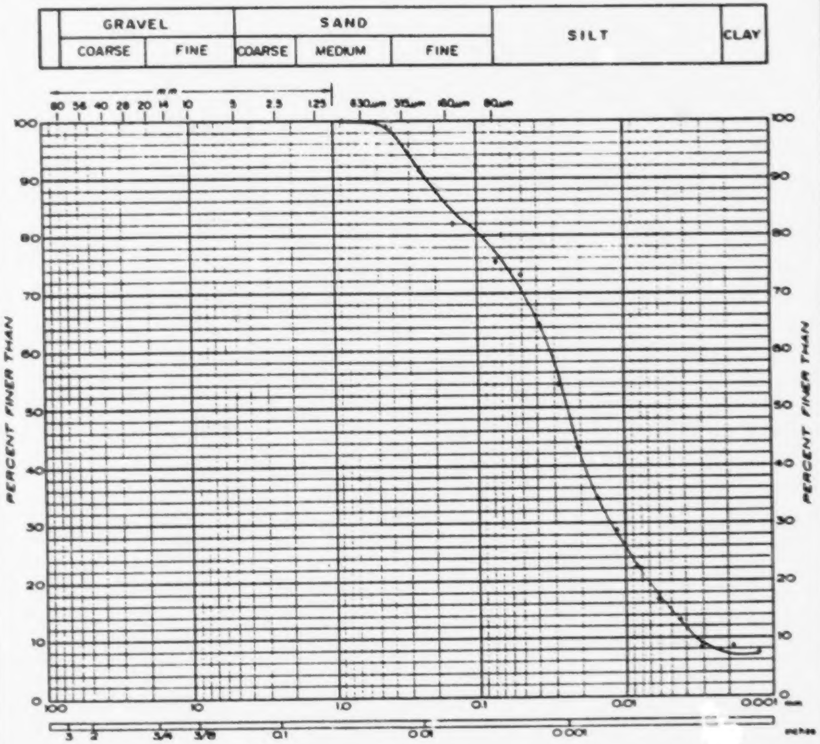
GRAIN SIZE DISTRIBUTION

Test Hole No. .... Sample No. ....
Depth ....

DRAWING NO.



D60: 0.033 D30: 0.013 D10: 0.0035

IN LABORATORY CHECK:
REMARKS SAMPLE C: COMBINED GM5A-S1, GM12A-S1, GM13A-S1, GM6A-S1
(WEST MAIN TAILINGS)

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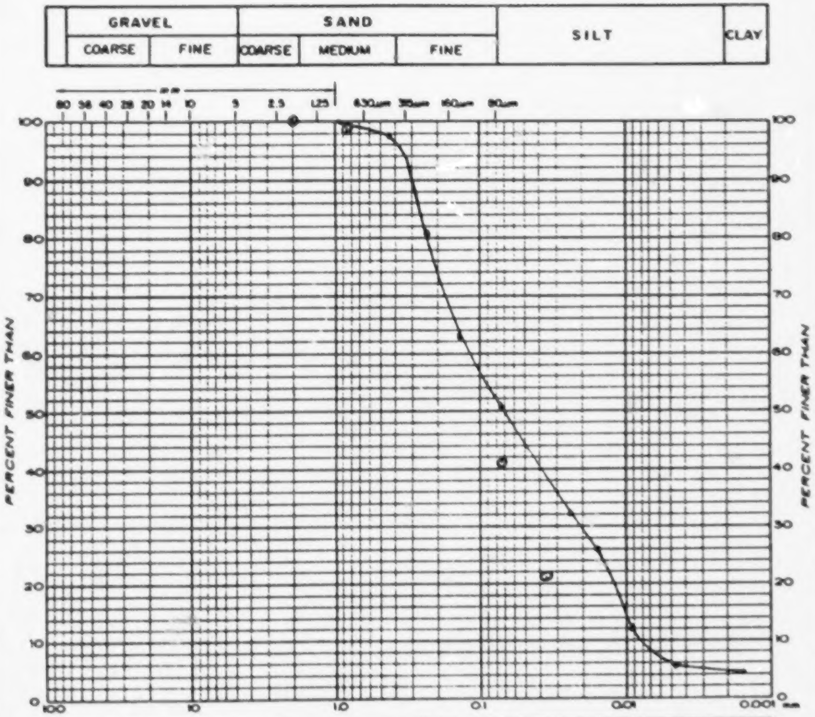
GRAIN SIZE DISTRIBUTION

Test Hole No. .... Sample No. ....
Depth ....

DRAWING NO.



D_{60}: 0.12 D_{30}: 0.020 D_{10}: 0.008

REMARKS SAMPLE C (WEST MAIN TAILINGS)

COMBINED GM5A-S1, GM12A-S1, GM13A-S1, GM6A-S1

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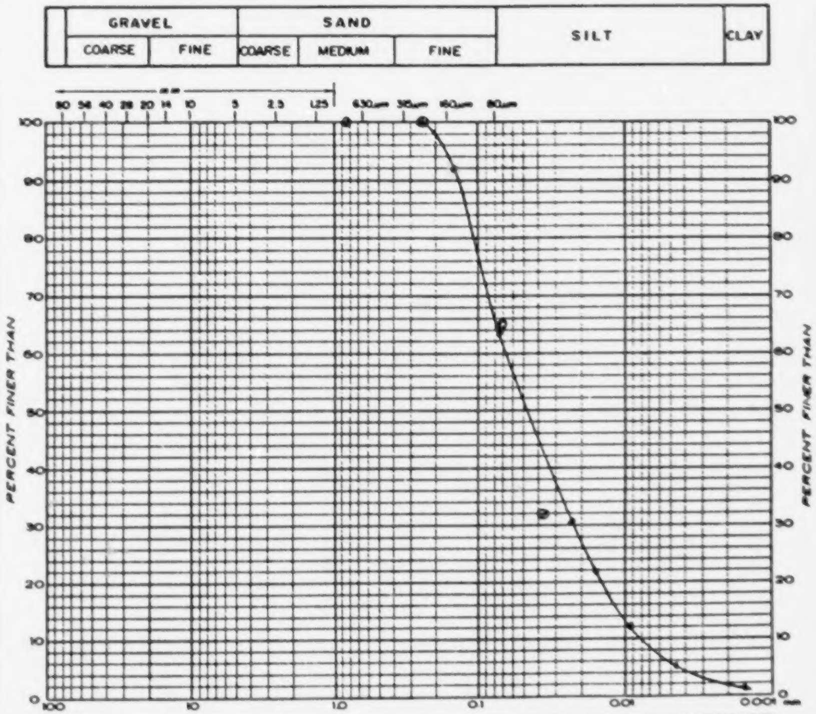
GRAIN SIZE DISTRIBUTION

Test Hole No. .... Sample No. ....
Depth ....

DRAWING NO.



D_{60}: 0.065 D_{30}: 0.023 D_{10}: 0.0083

REMARKS SAMPLE D: (LANGLEY BAY)

COMBINED LB2A-S1, LB7A-S1

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GRAIN SIZE DISTRIBUTION

Test Hole No. .... Sample No. ....
Depth COMB.

DRAWING NO.

4.4.4 Geotechnical Test Results

Table 4.2 presents a summary of geotechnical test results for moisture content (partial), Atterberg Limits, density, specific gravity, and permeablity. Grain size distribution curves were presented in the previous section. Triaxial test results are presented in Table 4.3 and Figure No. 4.8. The results of a consolidation test are reported on Figures Nos. 4.9 and 4.10.

TABLE 4.2
GEOTECHNICAL TEST RESULTS

								Field Density		Relative Density		Permeability		
Location	Depth m	USCS Class	Soil Type	Water (%)	Pw (%)	Lw (%)	S. G.	(kg/m3)	Type	Min (kg/m3)	Max (kg/m3)	Density (kg/m3)	Coeff. (cm/s)	Type
N1A-S1	3.7	SM	TA	15.6				1489	BQ	1305	2163	1353	4.7E-04	PO
N1A-S2	6.7	ML	TA	14.2										
N1B-S3	5.2	SM	TA	8.9										
N1C-S1	0	SM	TA	8.2				1410	BQ					
N1C-S2	1.5	SM	TA	7.1				1037	BQ	1365	1821	1364	1.1E-03	PO
N1C-S3	3.0	SM	TA	8.4	NP	NP	2.596	1350	BQ					
N1C-S4	4.6	SM	TA	12.8										
N1C-S5	6.1	SM	TA	13.2	NP	NP	2.65	1669	BQ					
N1C-S6	7.6	SM	TA	17.2				1574	BQ					
N1C-S7	9.1	SM	TA	15.4				1664	BQ					
N1C-S7D	9.1	SM	TA	16.1										
N1C-S8	10.7	SM	TA	14.8				1652	BQ					
N1C-S9	11.3	SM	TA	14.9				1380	BQ	1263	1663	1555	1.1E-04	PO
N1C-S9D	11.3	SM	TA	21.6								1658	4.4E-06	CON
N1D-S1	3.1	SM	TA	7.6	NP	NP	2.719	1719	ST				1.8E-03	ST
N1E-S1	0	SM	TA	8.3				1226	BQ					
N1E-S4	1.5	SP	TA	3.9										
N1E-S6	2.1	SP	TA	5.5	NP	NP		1590	ST				1.1E-03	ST
N1E-S8	2.8	SP	TA	7.3				1410	ST					
N1E-S9	4.2	SM	TA	8.6			2.678	1610	BQ			1665	8.2E-05	PO
N1E-S9D	4.2	SM	TA											
N1E-S10	4.6	SM	TA	10.9			2.707	1459	ST				8.7E-04	ST
N1E-S12	6.1	SM	TA	17.1				1750	ST					
N1E-S13	8.6	SM	TA	18.5				2027	BQ					
N1E-S14	9.2	SP	TA	14.9				1854	ST				5.6E-05	ST
N1E-S17	13.4	ML	TA	15.8										
N2A-S1	2.1	ML	TA	65.4										
N2A-S2	4.9	SM	TA	20.8										
N2B-S3	3.0	ML	TA	28.2										
N2C-S4	1.5	SM	TA	25.6										
N2C-S4D	1.5	SM	TA	22.5	NP	NP								
N2D-S5	0.6	SM	TA	24.4										
N2E-S1	0	SP	TA	6.2										
N2E-S4	2.4	SM	TA	21.3	NP	NP		1660	ST				U/S	ST
N2E-S6	3.4	ML	TA	19.5				1726	ST					
N2E-S7	4.6	SM	TA	19.8	NP	NP		1725	ST				1.9E-04	ST
N2E-S8	5.5	SM	TA	22.9			2.679	1749	BQ			1628	3.2E-04	PO
N2E-S9	6.1	SM	TA	19.1	NP	NP		1646	ST				1.4E-06	ST
N2E-S10	7.6	ML	TA	21.9	18.2	19		1642	ST				7.7E-05	ST
N2E-S12	9.1	SM	NA	38.7	NP	NP		1384	ST					
N2E-S14	12.2	ML-OL	NA	77.6	31.0	41.7		904	ST					
N2E-S16	19.0	CI	NA	37.6	21.8	33.2	2.681							
N3E-S3	1.5	SM	TA	27.6	NP	NP		1109	BQ	1243	1655	1275	5.1E-04	PO
N3E-S6	4.6	ML	TA	27.0				1104	BQ					
N3E-S7	5.2	ML-OL	NA	41.4	23.0	27.9								
N3E-S8	6.1	CI	NA	35.3										
N3E-S9	7.0	CI	NA	38.4				1229	BQ					
N3E-S10	8.2	CI	NA	39.6	21.9	31.7	2.714	1276	BQ					
N3E-S11	10.7	CI	NA	36.7										
N3E-S12	11.3	CI	NA	30.7										
N3E-S13	12.8	CI	NA	39.6	20.8	30.1								
N3E-S14	13.7	CI	NA	35.5										
N3F-S1	7.3	CI	NA	29.9	18.1	32.9		1473	ST				7.2E-06	ST
N3G-S1	2.0	ML	TA	24.5				1172	BQ					
N4A-S1	0	ML	TA	22.7				1228	BQ					
N4A-S2	1.5	ML	TA	28.8	27.0	28.7	2.73	1233	BQ					
N4A-S3	3.0	CL	TA	25.4										
N4A-S4	4.3	CL	NA	24.9										
N4A-S5	5.2	CL	NA	28.3	19.1	27.0								
N4B-S1	1.8	CL	TA	21.0	17.8	28.6	2.699	1631	ST				3.4E-06	ST
N4B-S2	3.0	CI	TA	39.4	22.7	40.1		1262	ST				U/S	ST
N5A-S1	0	ML	TA	37.3				1145	BQ					
N5A-S2	1.2	ML	TA	31.9				1151	BQ	1037	1453	1294	1.4E-04	PO
N5A-S3	2.1	ML	TA	34.9	24.6	31.9	2.732	969	BQ					
N5A-S4	3.0	OL	TA	50.7	NP	NP								
N5A-S5	4.3	CI	NA	64.5										
N5A-S6	5.2	MH	NA	58.1	42.0	50.6								
N5A-S7	6.1	CI	NA	26.9										
N5A-S8	7.6	CI	NA	33.0										
N5A-S9	9.2	CI	NA	38.4										
N5A-S10	10.7	CI	NA	40.6										
N5A-S11	12.2	CI	NA	39.4	23.0	33.7								
N5A-S12	13.7	CI	NA	37.1										
N5B-S1	1.8	ML	TA	48.6	20.2	26.6	2.854	1118	BQ				U/S	ST

ST-Shelby Tube; BQ-BQ Sample; IN-Insitu Sample; PO-Proctor Remolded; TA-Triaxial; CON-Consolidation; D-Duplicate
TA-Tailings; NA-Native Soil

TABLE 4.2 (contimued)

Location	Depth m	USCS Class	Soil Type	Water (%)	Pw (%)	Lw (%)	S. G.	Field (kg/m3)	Density Type	Relative Relative Density Min (kg/m3)	Max (kg/m3)	Permeability Density (kg/m3)	Coeff. (cm/s)	Type
N6A-S1	0.8	SM	TA	21.5										
N6A-S2	1.5	SM	TA	40.4										
N6A-S3	4.5	ML	TA	21.1										
N6A-S5	6.1	ML	NA	20.7	22.2	24.1		1594	ST				7.4E-07	TA
N6A-S7	8.5	CI	NA	36.0	21.9	41.0		1387	ST				5.7E-10	ST
GM1A-S1	0	ML	TA	27.2										
GM2A-S1	0	SP	TA	8.1										
GM2A-S4	3.0	SP	TA	26.5				1519	ST				7.5E-06	ST
GM2A-S6	5.5	SM	TA	23.6				1673	BQ			1676	2.7E-04	PO
GM2A-S7	6.1	SM	TA	18.1				1668	ST					
GM2D-S1	0.3		TA	4.9				1361	IN					
GM2D-S2	0.6		TA	4.7				1343	IN					
GM2D-S3	0.9		TA	14.3				1278	IN					
GM2D-S4	1.2		TA	7.0				1324	IN					
GM3A-S1	0	SP	TA	7.9										
GM3A-S3	2.4	ML	TA	22.7			2.687	1695	BQ			1433	2.2E-04	PO
GM3A-S4	3.3	SM	TA	24.1			2.672	1556	ST				5.4E-04	ST
GM3A-S7	6.1	SM	TA	19.5				1697	ST				2.6E-04	ST
GM3A-S8	8.6	ML	TA	24.6				1634	BQ					
GM3A-S9	9.1	SM	TA	28.2				1509	ST					
GM4A-S1	0	ML	TA	36.5										
GM4A-S2	0.6	SM	TA	14.7				1245	IN					
GM5A-S1	0	SP	TA	15.4										
GM6A-S4	4.2	ML	TA	32.6										
GM6A-S5	7.6	ML	TA	33.5										
GM6C-S1	0.15		TA	10.8				1197	IN					
GM6C-S2	0.3		TA	26.3				1085	IN					
GM6C-S3	0.6		TA	16.3				1213	IN					
GM6C-S4	0.9		TA	28.3				1235	IN					
GM6C-S5	1.2		TA	28.0				1400	IN					
GM7A-S1		SM	TA	37.1										
GM8A-S1	0	SP	TA	16.7										
GM8A-S1D	0	SP	TA											
GM9A-S3	4.1	CL	TA	19.6	15.5	28.9		1632	ST				8.3E-07	ST
GM10A-S1	0	SP	TA	10.6										
GM11A-S1	0	SP	TA	5.5										
GM12A-S2	1.2	ML	TA	53.1	24.8	32.3								
GM12A-S4	3.4	CI	NA	17.8				1277	ST					
GM13A-S1	0	ML	TA	33.2										
GM13A-S2	1.6	ML	TA	28.6			2.779	1031	BQ					
GM13A-S2D	1.6	ML	TA											
GM13A-S3	3.0	ML	TA	28.6	21.0	23.8		1220	ST					
GM13A-S5	6.1	CI	TA	40.7	22.3	31.2		1308	ST				2.1E-07	TA
GM13A-S6	7.6	ML	NA	50.3	32.0	46.1		1099	ST				U/S	
GM17A-S6	0	ML	TA	42.6										
GM18A-S1	0	SM	TA	26.1										
GM19A-S3	0	ML	TA	31.4										
GM20-S1	0.3		TA	4.7				1327	IN					
GM20-S2	0.6		TA	4.5				1384	IN					
GM20-S3	0.9		TA	4.8				1409	IN					
GC5A-S1	1.5	ML	TA	27.9										
GC5A-S5	4.6	CL	NA	24.9	18.0	25.8		1255	ST				3.1E-06	ST
GC5A-S9	0	SM	TA	28.8	NP	NP								
LB2A-S1	0	ML	TA											
LB2A-S3	1.9	CI	TA	39.7	24.0	40.0		1053	ST					
LB2A-S4	2.5	ML	TA	45.3			2.767							
LB2A-S5	3.1	ML	TA	39.0				1404	ST					
LB2A-S7	4.6	MH-OH	NA	86.3	40.1	60.7		1296	ST				U/S	ST
LB2A-S11	19.2	CI	NA	40.4	22.5	36.2								
LB2A-S11D	19.2	CI	NA											
LB3B-S3	4.3	OL	NA	72.9	32.4	48.4								
LB7A-S2	1.2	ML-SM	TA	35.6	NP	NP								
LB7A-S3	1.8	ML	TA	29.2				1375	ST					
LB7A-S5	3.1	OH	NA	57.6	36.1	54.3			1342	ST			U/S	ST
LB7A-S8	10.9	CL	NA	39.9	20.0	25.0								
COMBA														
COMBB														
COMBC														
COMBC2														
COMD														
WR2-S1	19.6		NA											
WR3-S1	28.2		NA											
WR4-S1	14.6		NA											
WR5-S1	25.4		NA											

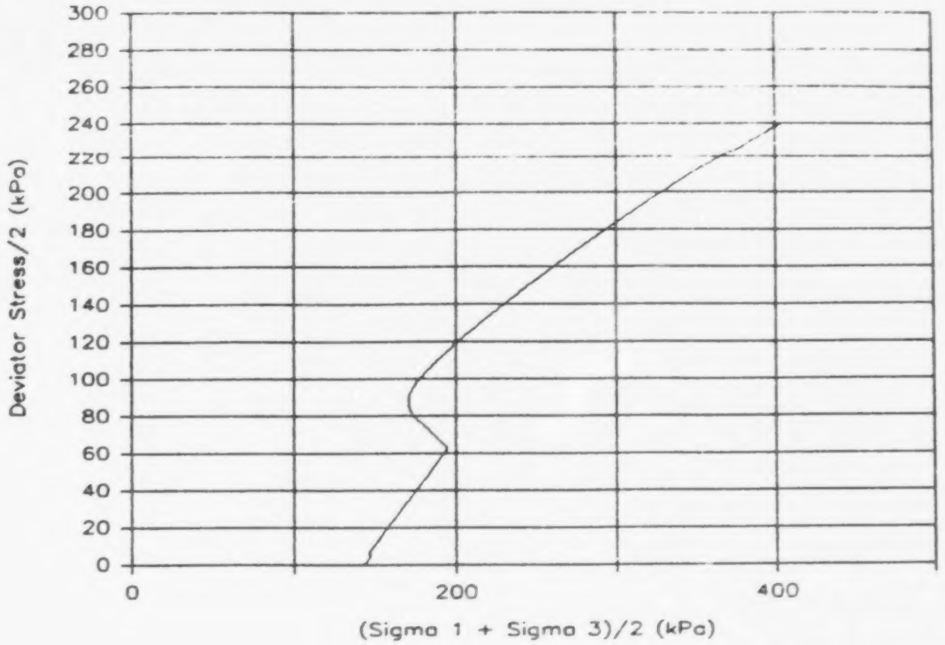
ST-Shelby Tube; BQ-BQ Sample; IN-Insitu Sample; PO-Proctor Remolded; TA-Triaxial; CON-Consolidation; D-Duplicate
TA-Tailings; NA-Native Soil

TABLE 4.3
SUMMARY OF TRIAXIAL TEST RESULTS

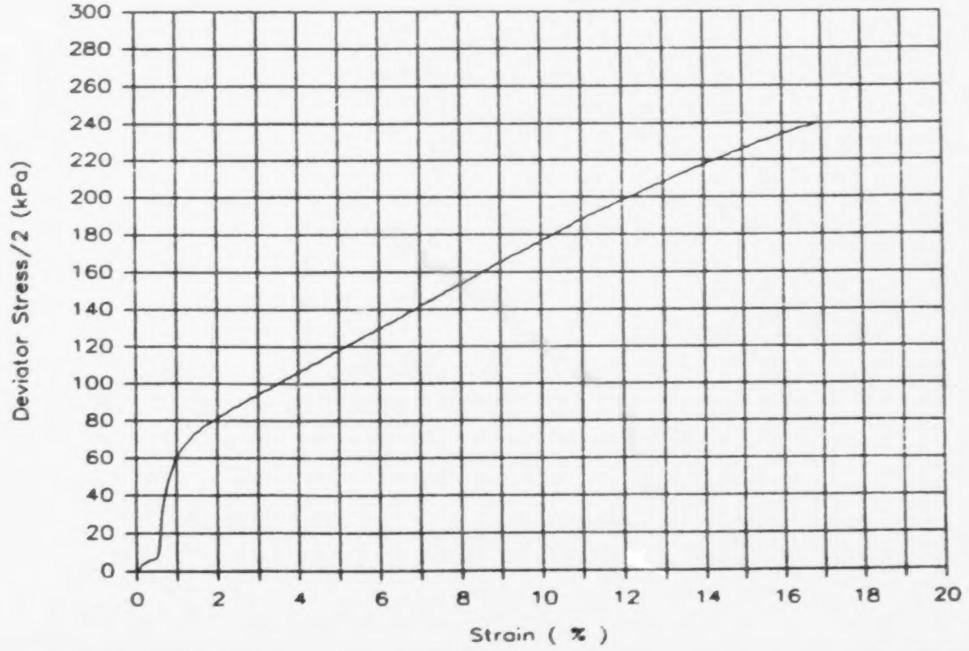
(Description - CLAY TAILINGS, silty, wet, firm, medium plastic, reddish brown)

Test Hole No.	GM13A	Depth (m)	6.1 - 6.6
Sample diameter - m	0.0489	Cell pressure - kPa	380
Sample height - m	0.101	Back pressure - kPa	234
Failure rate - mm/min	0.0574	Consol. pressure - kPa	146
Initial moisture - %	40.7	Final moisture - %	33.7
Dry density - kg/m3	1308	B - before consol.	0.97
Liquid limit - %	31.2	Plastic limit - %	22.3

TRIAXIAL STRESS PATH



TRIAXIAL STRESS STRAIN



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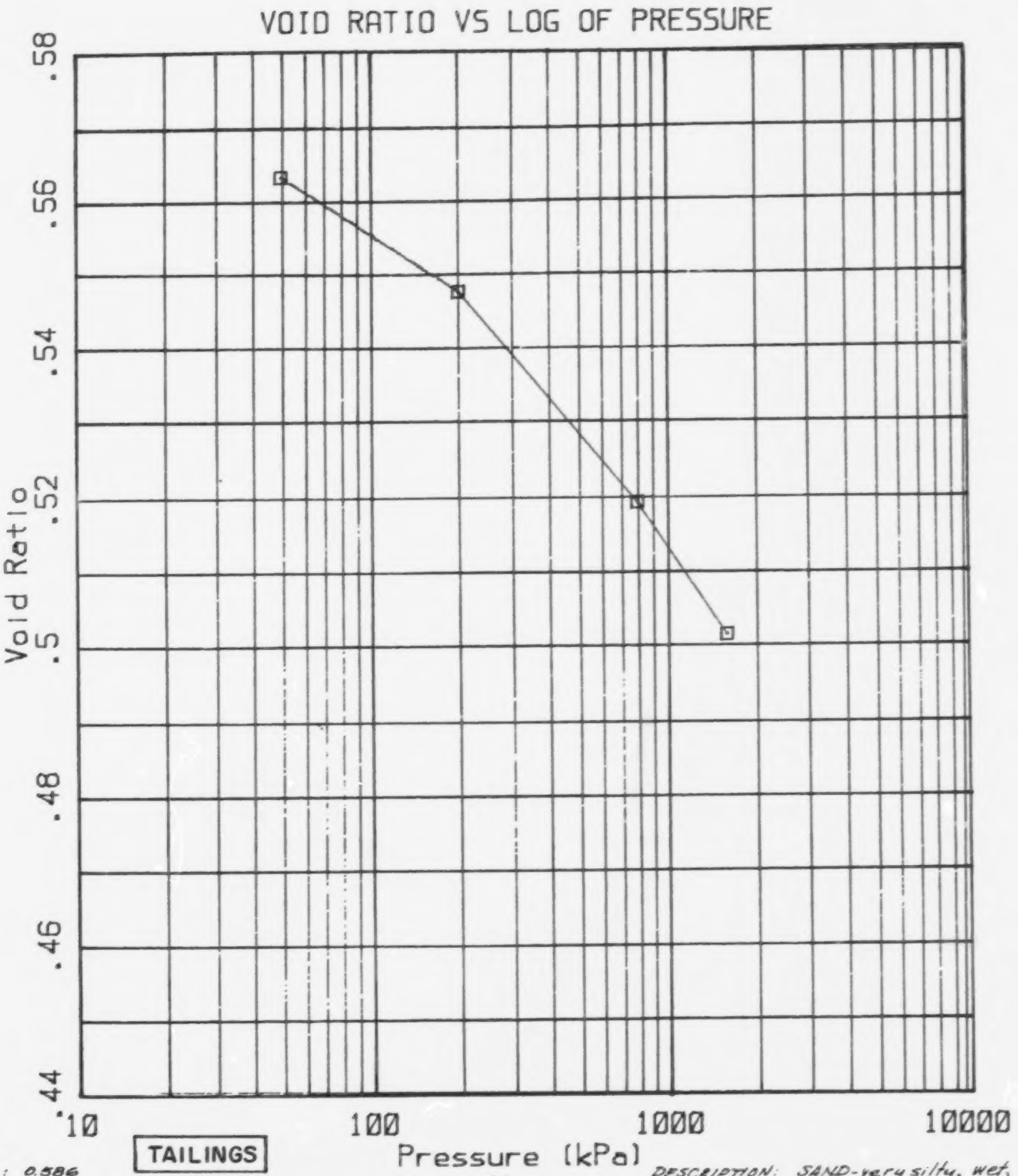
TRIAXIAL TEST RESULTS

Test Hole GM 13A
Depth 6.1m

FIGURE 4.8

VOID RATIO VS LOG OF PRESSURE



TAILINGS

e_o : 0.586

$k_{(200)}$: 4.4 x 10^{-6} cm/s

W : 21.6%

DENSITY: 1658 kg/m³

DESCRIPTION: SAND-very silty, wet, medium dense, reddish brown.

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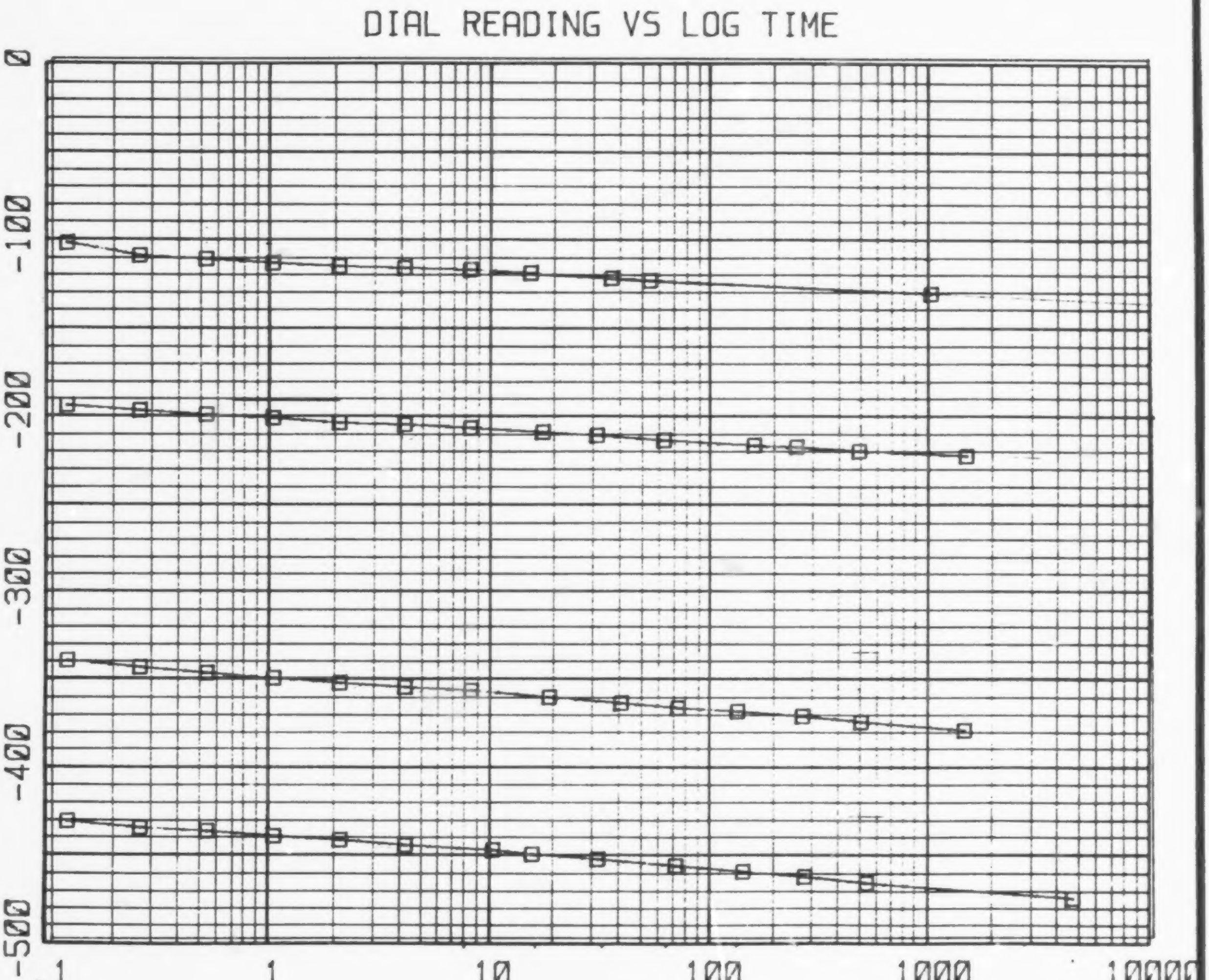
CONSOLIDATION TEST

Test Hole NIC
Sample 9
Depth 11.3

FIGURE 4.9



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CONSOLIDATION TEST

Test Hole N1C
Sample 9
Depth 11.3 m

FIGURE 4.10

4.4.5 Geochemical Test Results

Tables 4.4 to 4.15 present the results of the chemical and radionuclide tests performed on the tailings solids.

TABLE 4.4 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN NI

Location	SE Side Gunnar Main							SE Side Gunnar Main						
Depth from Surface	3 to 3.6 m							6.1 to 6.7 m						
Parent Material	Sand, silty, reddish brown tailings							Sand, silty, reddish brown tailings						
Field Code	NIC (S3A)							NIC (S5A)						
Date	84.12.09							84.12.09						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter														
pH of Leach Water	7.0	-	-	-	-	-	-	7.0	-	-	-	-	-	-
IC Scan (Anions):														
Bromide	L 17	-	-	-	-	-	L 17	L 17	-	-	-	-	-	L 17
Chloride	25	-	-	-	-	-	25	86	-	-	-	-	-	86
Fluoride	5.1	-	-	-	-	-	5.1	8.3	-	-	-	-	-	8.3
O-Phosphate	L 17	-	-	-	-	-	L 17	L 17	-	-	-	-	-	L 17
Sulphate	13,600/ 13,200	- -	- -	- -	-	- -	13,000/ 13,200	17,800/ 17,500	- -	- -	- -	- -	- -	17,800/ 17,500
Nitrate	L 17	-	-	-	-	-	L 17	L 17	-	-	-	-	-	L 17
Major Cations:														
Magnesium	54	0.39	13,700	98.6	187	1.34	13,900	89	0.56	15,400	97.5	320	20.2	15,800
Calcium	4,900	60.5	2,700	33.3	500	6.17	8,100	6,300	65.6	3,100	32.3	390	3.98	9,800
Iron	9.5	0.05	17,700	90.3	1,940	9.90	19,600	6.9	0.03	21,000	86.8	3,200	13.2	24,200
Manganese	0.7	0.28	240	97.6	5	2.03	246	0.7	0.24	280	97.9	5	1.75	286
Silica SiO_2	240	0.04	600	0.10	580,000	99.8	581,000	220	0.04	1,030	0.17	590,000	99.8	591,000
Aluminum	17	0.02	9,500	11.2	75,000	88.8	84,500	16	0.02	10,600	11.3	83,000	88.3	94,000
Sodium	115	0.17	330	0.48	69,000	99.4	69,400	330	0.35	480	0.51	93,000	98.9	94,000
Potassium	34	0.38	640	7.19	8,200	92.1	8,900	53	0.62	630	7.41	7,800	91.8	8,500
Trace Cations:														
Strontium	5.8	14.5	9.1	22.8	25	62.7	39.9	7.3	17.1	10.4	24.4	25	58.5	42.7
Lead	2	0.83	220	91.7	18	7.50	240	4.0	1.79	154	68.8	66	29.5	224
Cobalt	0.7	10.8	4.8	73.8	1	15.3	6.5	0.7	4.79	5.9	40.4	8	54.8	14.6
Nickel	0.7	8.30	5.7	67.9	2	23.8	8.4	0.7	3.59	6.8	34.9	12	61.5	19.5
Zinc	0.3	0.93	32	16.1	L 1	-	32.3	L 0.3	-	28	87.5	4	12.5	32

TABLE 4.4 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN NI

Location	SE Side Gunnar Main							SE Side Gunnar Main						
Depth from Surface	3 to 3.6 m							6.1 to 6.7 m						
Parent Material	Sand, silty, reddish brown tailings							Sand, silty, reddish brown tailings						
Field Code	NIC (S7A)							NIC (S5A)						
Date	84.12.09							84.12.09						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	1.0	4.17	17.7	73.8	5	20.8	24	0.7	1.85	24	63.2	13	34.2	38
Copper	0.7	2.80	17.9	71.6	6	24.0	25	0.7	2.41	22	75.9	6	20.7	29
Cadmium	L 0.3	-	5.2	100	L 2	-	5.2	L 0.3	-	6.0	100	L 2	-	6.0
Barium	4.4	1.69	190	73.1	66	25.4	260	3.3	1.40	188	80.0	44	18.7	235
Vanadium	0.50	1.35	18.9	51.1	18	48.6	37	0.50	1.02	24.2	49.4	24	490	49
Titanium	3.4	0.25	95	6.93	1,270	92.7	1,370	4.0	0.23	109	6.37	1,600	93.6	1,710
Arsenic	0.37	6.17	5.6	93.3	-	-	6.0	0.50	6.17	7.6	93.8	-	-	8.1
Selenium	L 0.02	-	0.46	100	-	-	0.46	L 0.02	-	0.15	100	-	-	0.15
Molybdenum	1.7	32.7	3.5	67.3	L 2	-	5.2	1.6	28.6	4.0	71.4	L 2	-	5.6
Beryllium	L 0.17	-	2.0	66.7	1	33.3	3.0	L 0.17	-	2.1	67.7	1	32.3	3.1
Total Sulphur (%)	-	-	-	-	-	-	L 0.01	-	-	-	-	-	-	L 0.01
Total Carbonate (%)	-	-	-	-	-	-	0.51	-	-	-	-	-	-	0.62
Sum Anions	279	-	-	-	-	-	-	369	-	-	-	-	-	-
Sum Cations	257	-	-	-	-	-	-	339	-	-	-	-	-	-
Radionuclides														
Uranium (ug/g)	0.0015	0.0023	29	50	-	-	58//29	-	-	-	-	-	-	40
Thorium-230 (Bq/g)	0.0015	0.05	3.0	100	-	-	3.0//3.0	-	-	-	-	-	-	5.0
Radium-226 (Bq/g)	0.0242	0.3	6.5	81	-	-	8.0//6.5	-	-	-	-	-	-	8.0
Lead-210 (Bq/g)	0.0067	0.08	8.0	100	-	-	8.0//8.0	-	-	-	-	-	-	9.0
Polonium-210 (Bq/g)	0.0013	0.02	6.0	100	-	-	5.5//6.0	-	-	-	-	-	-	7.0
Radium-228 (Bq/g)	0.0008	0.7	.09	82	-	-	0.11//0.09	-	-	-	-	-	-	0.11
LOI %							1.0							1.3

/ = Internal replicate.
// = Blind replicate.

TABLE 4.4 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN NI

Location	SE Side Gunnar Main							SE Side Gunnar Main				
Depth from Surface	9.1 to 9.7 m							6.1 to 6.7 m				
Parent Material	Sand, silty, reddish brown tailings							Sand, silty, reddish brown tailings				
Field Code	NIC (S7A)							NIC (S5B) SRC Data				
Date	84.12.09							84.12.09				
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion Total (ug/g)
Parameter												
pH of Leach Water	7.3	-	-	-	-	-	-	-		-		-
IC Scan (Anions):												
Bromide	L 17	-	-	-	-	-	L 17	L 20		-		-
Chloride	23	-	-	-	-	-	23	106		-		-
Fluoride	6.8	-	-	-	-	-	6.8	L 2		-		320
O-Phosphate	L 17	-	-	-	-	-	L 17	1.2		367		428
Sulphate	11,900/ 11,200	-	-	-	-	-	11,900/ 11,200	13,800		-		14,000
Nitrate	L 17	-	-	-	-	-	L 17	20		-		-
Major Cations:												
Magnesium	146	1.05	13,400	96.4	340	2.45	13,900	37	0.26	13,500	96.4	14,000
Calcium	3,700	43.5	4,500	52.9	320	3.76	8,500	5,400	60.0	8,800	97.8	9,000
Iron	4.7	0.02	17,500	84.1	3,300	15.9	20,800	10	0.05	14,000	70.0	20,000
Manganese	2.7	0.93	280	96.9	7	2.42	289	0.12	0.09	130	92.9	140
Silica SiO_2	180	0.03	560	0.10	580,000	99.8	581,000	-	-	1,350	-	545,000
Aluminum	14	0.02	10,800	11.8	80,000	88.1	90,800	14	0.12	10,000	83.3	12,000
Sodium	136	0.16	330	0.38	87,000	99.4	87,500	320	32.3	895	90.4	990
Potassium	44	0.29	1,160	7.53	14,200	92.2	15,400	92	9.20	750	75.0	1,000
Trace Cations:												
Strontium	5.4	13.8	12.8	32.6	21	53.6	39.2	4	-	-	-	12
Lead	2.7	1.44	151	80.3	34	18.1	188	0.07	0.05	145	96.7	150
Cobalt	0.3	4.69	5.1	79.7	1	15.6	6.4	L 0.02	-	2.5	83.3	3.0
Nickel	0.3	5.26	5.4	94.7	L 1	-	5.7	L 0.02	-	3.4	91.2	3.1
Zinc	0.3	0.99	26	85.8	4	13.2	30.3	0.52	2.26	21	91.3	23

TABLE 4.4 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN NI

Location	SE Side Gunnar Main							SE Side Gunnar Main				
Depth from Surface	9.1 to 9.7 m							6.5 to 6.7 m				
Parent Material	Sand, silty, reddish brown tailings							Sand, silty, reddish brown tailings				
Field Code	NIC (S7A)							NIC (S5B) SRC Data				
Date	84.12.09							84.12.09				
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion Total (ug/g)
Chromium	0.3	1.20	16.2	64.8	8	32.0	25	0.034	-	17	-	13
Copper	0.7	3.76	10.9	58.6	7	37.6	18.6	0.041	1.60	21	84.0	25
Cadmium	0.3	5.66	5.0	94.3	L 2	-	5.3	L 0.02	-	L 0.3	-	L 0.3
Barium	3.0	1.16	175	67.6	81	31.3	259	1.1	0.38	210	72.4	290
Vanadium	0.50	1.00	33.2	66.4	16	32	50	L 0.2	-	25	75.7	33
Titanium	3.4	0.22	83	5.25	1,490	94.3	1,580	0.029	0.01	70	31.8	220
Arsenic	0.20	3.45	5.6	96.6	-	-	5.8	0.41	3.73	10	90.9	11
Selenium	L 0.02	-	0.08	100	-	-	0.08	0.14	40	0.075	21.4	0.35
Molybdenum	1.4	26.9	3.8	73.1	L 2	-	5.2	L 0.05	-	L 1	-	L 2
Beryllium	L 0.17	-	3.5	77.8	1	22.2	4.5	L 0.02	-	6	75.0	8
Total Sulphur (%)	-	-	-	-	-	-	L 0.01					
Total Carbonate (%)	-	-	-	-	-	-	0.70					
Sum Anions	241	-	-	-	-	-	-	291		-		-
Sum Cations	206	-	-	-	-	-	-	291		-		-
Radionuclides												
Uranium (ug/g)	-	-	-	-	-	-	-	0.0011	0.0015	40	54	74
Thorium-230 (Bq/g)	-	-	-	-	-	-	-	0.0008	0.02	5.0	100	4.5
Radium-226 (Bq/g)	-	-	-	-	-	-	-	0.0246	0.26	8.0	84	9.5
Lead-210 (Bq/g)	-	-	-	-	-	-	-	0.0031	0.03	9.0	95	9.5
Polonium-210 (Bq/g)	-	-	-	-	-	-	-	0.0012	0.02	7.0	93	7.5
Radium-228 (Bq/g)	-	-	-	-	-	-	-	0.0012	0.48	0.11	44	0.25
LOI %							1.3					2.4

TABLE 4.4 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N1

Location	Gunnar Main					Gunnar Main				
Depth from Surface	0.3 to 0.7 m					9.2 to 9.8 m				
Parent Material	Reddish brown, silty, sand tailings					Reddish brown, silty, sand tailings				
Field Code	NIE (S2)					NIE (S14)				
Date	85.03.26					85.03.26				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter										
pH of Leach Water										
IC Scan (Anions):										
Bromide	L 13	-	-	-	L 13	L 5	-	-	-	L 5
Chloride	32	-	-	-	32	19	-	-	-	19
Fluoride	L 1	-	-	-	L 1	3.4	-	-	-	3.4
O-Phosphate	L 64	-	-	-	L 64	19	-	-	-	19
Sulphate	14,700	-	-	-	14,700	6,000	-	-	-	6,000
Nitrate	L 3	-	-	-	L 3	L 1	-	-	-	L 1
Major Cations:										
Magnesium	262	1.76	14,600	98.0	14,900	269	2.17	12,100	97.6	12,400
Calcium	6,980	69.1	3,100	30.7	10,100	2,880	44.4	3,600	55.6	6,480
Iron	230	1.14	20,000	99.0	20,200	360	1.76	20,000	98.0	20,400
Manganese	4.5	2.38	185	97.9	189	5.3	2.82	183	97.3	188
Silica SiO_2	1,280	0.21	610,000	99.8	611,000	960	0.17	550,000	99.8	551,000
Aluminum	250	0.30	82,000	99.8	82,200	250	0.32	78,000	99.7	78,200
Sodium	205	0.37	55,000	99.6	55,200	130	0.27	48,000	99.8	48,100
Potassium	96	1.03	9,200	98.9	9,300	139	1.08	12,800	99.2	12,900
Trace Cations:										
Strontium	8.3	16.3	43	84.3	51	3.8	11.5	29	87.9	33
Lead	6.4	7.44	80	93.0	86	7.7	12.6	53	86.9	61
Cobalt	L 0.6	-	6	100	6	0.5	20.0	2	80.0	2.5
Nickel	L 0.6	-	9	100	9	0.5	20.0	2	80.0	2.5
Zinc	L 0.6	-	45	97.8	46	0.5	2.08	24	98.9	24

TABLE 4.4 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN NI

Location	Gunnar Main					Gunnar Main				
Depth from Surface	0.3 to 0.7 m					9.2 to 9.8 m				
Parent Material	Reddish brown, silty, sand tailings					Reddish brown, silty, sand tailings				
Field Code	NIE (S2)					NIE (S14)				
Date	85.03.26					85.03.26				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	0.6	2.30	25	96.1	26	1.9	7.04	25	92.6	27
Copper	0.6	2.07	28	96.6	29	0.5	4.76	10	95.2	10.5
Cadmium	L 0.6	-	L 2	-	-	L 0.5	-	L 2	-	-
Barium	8.3	3.81	210	96.3	218	8.2	2.85	280	97.2	288
Vanadium	0.6	1.28	46	97.8	47	1.0	2.33	42	97.7	43
Titanium	9.0	0.64	1,390	99.3	1,400	17	1.19	1,410	98.6	1,430
Arsenic	0.3	3.75	7.7	96.3	8.0	0.6	8.57	6.4	91.4	7.0
Selenium	0.03	13.0	0.2	87.0	0.23	0.02	-	L 0.1	-	-
Molybdenum	1.3	100	L 2	-	1.3	0.5	100	L 2	-	0.5
Beryllium	0.3	13.0	2	87.0	2.3	0.2	9.09	2	90.9	2.2
Total Sulphur (%)										
Sum Anions										
Sum Cations										
Radionuclides										
Uranium (ug/g)	-	-	-	-	60	-	-	-	-	74
Thorium-230 (Bq/g)	-	-	-	-	4.0	-	-	-	-	3.5
Radium-226 (Bq/g)	-	-	-	-	7.0	-	-	-	-	7.0
Lead-210 (Bq/g)	-	-	-	-	6.0	-	-	-	-	6.0
Polonium-210 (Bq/g)	-	-	-	-	4.5	-	-	-	-	4.5
Radium-228 (Bq/g)	-	-	-	-	-	-	-	-	-	-
Thorium-232 (Bq/g)	-	-	-	-	0.25	-	-	-	-	0.30
Thorium-228 (Bq/g)	-	-	-	-	0.25	-	-	-	-	0.25
LOI %										

TABLE 4.5 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N2

Location	Mid-south End Gunnar Main							Mid-south End Gunnar Main						
Depth from Surface	4.9 to 5.5 m							3.1 to 3.7 m						
Parent Material	Sand, some silt, dark brown tailings							Silt, very sandy, reddish brown tailings						
Field Code	N2A (S2A)							N2B (S3A)						
Date	84.12.02							84.12.03						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter														
pH of Leach Water	6.7	-	-	-	-	-	-	6.2	-	-	-	-	-	-
IC Scan (Anions):														
Bromide	L 27	-	-	-	-	-	L 27	L 28	-	-	-	-	-	L 28
Chloride	62	-	-	-	-	-	62	230/210	-	-	-	-	-	230/210
Fluoride	5.9	-	-	-	-	-	5.9	91	-	-	-	-	-	91
O-Phosphate	L 27	-	-	-	-	-	L 27	L 28	-	-	-	-	-	L 28
Sulphate	27,100	-	-	-	-	-	27,100	67,000	-	-	-	-	-	67,000
Nitrate	L 27	-	-	-	-	-	L 27	L 28	-	-	-	-	-	L 28
Major Cations:														
Magnesium	132	0.90	14,300	97.3	240	1.63	14,700	350	2.01	16,800	96.6	240	13.8	17,400
Calcium	9,400	90.4	660	6.35	290	2.79	10,400	24,000	96.7	500	2.02	340	1.37	24,800
Iron	5.1	0.02	20,600	94.9	1,130	5.21	21,700	4.0	0.02	23,000	92.7	1,830	7.34	24,800
Manganese	4.6	1.84	240	96.0	5	0.80	250	12.5	4.63	250	92.6	6	2.22	270
Silica SiO_2	220	0.04	1,070	0.18	580,000	99.8	581,000	390	0.07	820	0.15	550,000	99.8	551,000
Aluminum	16	0.02	11,700	11.7	83,000	87.6	99,700	34	0.04	13,500	15.6	73,000	84.4	86,500
Sodium	177	0.24	410	0.56	73,000	99.2	73,600	400	0.60	490	0.74	65,000	98.6	65,900
Potassium	43	0.44	960	9.90	8,700	89.7	9,700	40	0.42	1,050	11.1	8,400	88.5	9,490
Trace Cations:														
Strontium	10.5	28.4	6.9	18.6	20	54.0	37	29	48.3	10.2	17.0	21	35.0	60
Lead	2.4	0.83	260	90.0	27	9.34	289	11.9	3.33	320	89.6	25	7.00	357
Cobalt	0.5	5.10	5.3	54.1	4	40.8	9.8	1.1	14.3	5.6	72.7	1	13.0	7.7
Nickel	0.3	3.53	7.2	84.7	1	11.8	8.5	1.1	10.3	6.6	61.7	3	28.0	10.7
Zinc	L 0.3	-	33	97.0	1	2.94	34	0.6	1.50	37	92.5	2	5.0	40
Chromium	0.8	2.29	26	74.3	8	22.9	35	3.4	9.44	25	69.4	8	22.2	36

TABLE 4.5 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N2

Location	Mid-south End Gunnar Main							Mid-south End Gunnar Main						
Depth from Surface	4.9 to 5.5 m							3.1 to 3.7 m						
Parent Material	Sand, some silt, dark brown tailings							Silt, very sandy, reddish brown tailings						
Field Code	N2A (S2A)							N2B (S3A)						
Date	84.12.02							84.12.03						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Copper	0.8	2.50	25	78.1	6	18.7	32	1.7	3.66	33	70.2	12	25.5	47
Cadmium	L 0.3	-	7.9	100	L 2	-	7.9	0.6	7.97	6.5	43.0	L 2	-	15.1
Barium	1.9	0.63	240	79.2	61	20.1	303	4.0	1.02	360	91.6	29	7.38	393
Vanadium	0.67	1.63	30.7	74.9	10	24.4	41	1.4	2.98	28.8	61.3	17	36.2	47
Titanium	5.4	0.34	111	7.03	1,460	92.4	1,580	11.3	0.62	108	5.93	1,700	93.4	1,820
Arsenic	0.11	1.36	8.0	98.8	-	-	8.1	0.23	2.58	8.6	96.6	-	-	8.9
Selenium	L 0.01	-	0.17	100	-	-	0.17	L 0.03	-	0.40	100	-	-	0.40
Molybdenum	2.2	42.3	3.0	57.7	L 2	-	5.2	4.5	57.0	3.4	43.0	L 2	-	7.9
Beryllium	L 0.13	-	3.0	75.0	1	25.0	4.0	0.28	6.09	3.3	71.7	1	21.7	4.6
Total Sulphur (%)	-	-	-	-	-	-	L 0.01	-	-	-	-	-	-	L 0.01
Total Carbonate (%)	-	-	-	-	-	-	0.05	-	-	-	-	-	-	L 0.01
Sum Anions	565	-	-	-	-	-	-	1,405	-	-	-	-	-	-
Sum Cations	491	-	-	-	-	-	-	1,250	-	-	-	-	-	-
Radionuclides														
Uranium (ug/g)														
Thorium-230 (Bq/g)														
Radium-226 (Bq/g)														
Lead-210 (Bq/g)														
Polonium-210 (Bq/g)														
Radium-228 (Bq/g)														
LOI %							1.1							1.4

TABLE 4.5 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N2

Location	Mid-south End Gunnar Main
Depth from Surface	1.5 to 2.1 m
Parent Material	Sand, very silty, reddish brown tailings
Field Code	N2C (S4A)
Date	84.12.03

	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter							
pH of Leach Water	6.7	-	-	-	-	-	-
IC Scan (Anions):							
Bromide	L 44	-	-	-	-	-	L 44
Chloride	220	-	-	-	-	-	220
Fluoride	15	-	-	-	-	-	15
O-Phosphate	L 44	-	-	-	-	-	L 44
Sulphate	46,000	-	-	-	-	-	46,000
Nitrate	L 44	-	-	-	-	-	L 44
Major Cations:							
Magnesium	290	1.69	16,600	96.5	260	1.51	17,200
Calcium	17,100	95.0	700	3.89	210	1.17	18,000
Iron	5.3	0.02	21,000	87.5	3,000	12.5	24,000
Manganese	8.8	3.10	270	95.1	5	1.76	284
Silica SiO_2	330	0.06	650	0.11	590,000	99.8	591,000
Aluminum	26	0.03	12,700	14.0	78,000	86.0	90,700
Sodium	310	0.41	360	0.48	74,000	99.1	74,700
Potassium	35	0.35	890	8.90	9,100	91.0	10,000
Trace Cations:							
Strontium	18	38.3	9.3	19.8	20	42.6	47
Lead	4.8	1.42	300	88.5	34	10.0	339
Cobalt	0.9	13.4	5.8	86.6	L 1	-	6.7
Nickel	0.4	5.56	6.8	94.4	L 1	-	7.2
Zinc	0.4	0.82	37	75.5	12	24.5	49
Chromium	1.3	3.94	24	72.7	8	24.2	33

TABLE 4.5 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N2

Location	Mid-south End Gunnar Main						
Depth from Surface	1.5 to 2.1 m						
Parent Material	Sand, very silty, reddish brown tailings						
Field Code	N2C (S4A)						
Date	84.12.03						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Copper	1.3	3.17	32	78.0	8	19.5	41
Cadmium	L 0.4	-	6.5	100	L 2	-	6.5
Barium	3.5	0.95	310	84.2	54	14.7	368
Vanadium	1.1	3.06	27.4	76.1	8	22.2	36
Titanium	8.8	0.49	89	4.97	1,690	94.4	1,790
Arsenic	0.04	0.35	11.3	100	-	-	11.3
Selenium	L 0.02	-	0.28	100	-	-	0.28
Molybdenum	3.5	51.5	3.3	48.5	L 1	-	6.8
Beryllium	L 0.22	-	3.3	76.7	1	23.3	4.3
Total Sulphur (%)	-	-	-	-	-	-	L 0.01
Total Carbonate (%)	-	-	-	-	-	-	0.05
Sum Anions	964	-	-	-	-	-	-
Sum Cations	894	-	-	-	-	-	-
Radionuclides							
Uranium (ug/g)							
Thorium-230 (Bq/g)							
Radium-226 (Bq/g)							
Lead-210 (Bq/g)							
Polonium-210 (Bq/g)							
Radium-228 (Bq/g)							
LOI %							1.5

TABLE 4.5 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N2

Location	Gunnar Main					Gunnar Main					Gunnar Main
Depth from Surface	0.6 to 0.9 m					4.6 to 5.2 m					5.5 m
Parent Material	Reddish brown, silty, sand tailings					Reddish brown, silty, sand tailings					Reddish brown, silty, sand tail:
Field Code	N2E (S2)					N2E (S7)					N2E (S8)
Date	85.03.21					85.03.21					
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	
Parameter											
pH of Leach Water											
IC Scan (Anions):											
Bromide	L 40	-	-	-	L 40	L 9.6	-	-	-	L 9.6	
Chloride	48	-	-	-	48	48	-	-	-	48	
Fluoride	4.8	-	-	-	4.8	3.2	-	-	-	3.2	
O-Phosphate	L 160	-	-	-	L 160	L 32	-	-	-	L 32	
Sulphate	88,000	-	-	-	88,000	13,600	-	-	-	13,600	
Nitrate	L 8	-	-	-	L 8	L 2	-	-	-	L 2	
Major Cations:											
Magnesium	400	1.79	22,000	98.2	22,400	192	0.16	120,000	99.8	120,000	
Calcium	36,800	96.3	1,390	3.64	38,200	5,820	75.5	1,890	24.5	7,710	
Iron	168	0.60	28,000	99.3	28,200	38	0.21	18,100	99.8	18,100	
Manganese	4.0	1.27	310	98.7	314	1.9	1.18	159	98.8	161	
Silica SiO_2	960	0.20	470,000	99.8	471,000	275	0.05	560,000	99.9	560,000	
Aluminum	156	0.19	83,000	99.8	83,200	50	0.05	91,000	99.9	91,000	
Sodium	440	0.93	47,000	99.2	47,400	128	0.25	52,000	99.8	52,100	
Potassium	57	0.73	7,700	99.2	7,760	67	0.52	12,800	99.2	12,900	
Trace Cations:											
Strontium	42	54.5	35	45.5	77	7.0	19.4	29	80.5	36	
Lead	14	8.28	155	91.7	169	2.6	4.64	54	96.4	56	
Cobalt	2.4	25.5	7	74.5	9.4	0.3	100	L 1	-	0.3	
Nickel	1.6	13.3	10	83.3	12	0.3	100	L 1	-	0.3	
Zinc	1.6	3.72	41	95.3	43	0.3	1.07	28	98.9	28	

TABLE 4.5 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N2

Location	Gunnar Main					Gunnar Main					Gunnar Main
Depth from Surface	0.6 to 0.9 m					4.6 to 5.2 m					5.5 m
Parent Material	Reddish brown, silty, sand tailings					Reddish brown, silty, sand tailings					Reddish brown, silty, sand tailings
Field Code	N2E (S2)					N2E (S7)					N2E (S8)
Date	85.03.21					85.03.21					
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	
Chromium	2.4	6.49	35	94.6	37	0.6	2.86	20	95.2	21	
Copper	0.8	1.95	40	97.6	41	L 0.3	-	14	100	14	
Cadmium	0.8	100	L 2	-	0.8	L 0.3	-	L 2	-	-	
Barium	8.8	3.04	280	96.9	289	2.2	0.81	270	99.3	272	
Vanadium	1.6	3.20	48	96.0	50	0.3	0.94	32	99.1	32	
Titanium	21	1.09	1,900	99.0	1,920	4.5	0.35	1,290	99.7	1,290	
Arsenic	0.3	1.73	17	98.3	17.3	0.1	1.02	9.7	99.0	9.8	
Selenium	0.04	8.00	0.5	92.0	0.5	0.02	100	L 0.1	-	0.02	
Molybdenum	4	100	L 2	-	4.0	1.0	100	L 2	-	1.0	
Beryllium	0.4	11.8	3	88.2	3.4	L 0.2	-	4	100	4	
Total Sulphur (%)											
Sum Anions											
Sum Cations											
Radionuclides											
Uranium (ug/g)	-	-	-	-	76	-	-	-	-	53	55
Thorium-230 (Bq/g)	-	-	-	-	12.5	-	-	-	-	4.5	-
Radium-226 (Bq/g)	-	-	-	-	30	-	-	-	-	6.0	7.0
Lead-210 (Bq/g)	-	-	-	-	21	-	-	-	-	6.0	8.0
Polonium-210 (Bq/g)	-	-	-	-	11	-	-	-	-	4.0	8.0
Radium-228 (Bq/g)	-	-	-	-	-	-	-	-	-	-	-
Thorium-232 (Bq/g)	-	-	-	-	0.70	-	-	-	-	0.25	-
Thorium-228 (Bq/g)	-	-	-	-	0.70	-	-	-	-	0.25	-
LOI %											

TABLE 4.5 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N2

Location	Gunnar Main					Gunnar Main					Gunnar Main
Depth from Surface	7.6 to 8.2 m					12.2 m					19.0 m
Parent Material	Reddish brown, silty, sand tailings					Organic silt, medium plastic, grey					Clay, medium to highly plastic, g
Field Code	N2E (S10)					N2E (S14)					N2E (S16)
Date	85.03.21					85.03.21					
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	
Parameter											
pH of Leach Water											
IC Scan (Anions):											
Bromide	L 11	-	-	-	L 11	L 10	-	-	-	L 10	
Chloride	61	-	-	-	61	77	-	-	-	77	
Fluoride	3.6	-	-	-	3.6	2.9	-	-	-	2.9	
O-Phosphate	L 36	-	-	-	L 36	L 24	-	-	-	L 24	
Sulphate	16,900	-	-	-	16,900	13,000	-	-	-	13,000	
Nitrate	L 2	-	-	-	L 2	L 1	-	-	-	L 1	
Major Cations:											
Magnesium	230/264	1.44/1.75	15,800/14,800	98.8/98.0	16,000/15,100	490	4.76	9,800	95.1	10,300	
Calcium	8,000/8,000	84.2/86.4	1,500/1,260	15.8/13.6	9,500/9,260	4,900	37.7	8,100	62.3	13,000	
Iron	36/88	0.19/0.51	19,000/17,300	99.8/99.4	19,000/17,400	67	0.35	19,000	99.5	19,100	
Manganese	4.5/5.6	2.53/3.41	174/158	97.8/96.3	178/164	24	9.45	230	90.6	254	
Silica SiO_2	288/472	0.06/0.09	510,000/500,000	99.9/99.9	510,000/500,000	514	0.10	520,000	99.9	520,000	
Aluminum	52/100	0.06/0.12	88,000/84,000	99.9/99.9	88,100/84,100	254	0.44	58,000	99.7	58,200	
Sodium	147/160	0.26/0.27	56,000/58,000	99.8/99.8	56,100/58,200	144	0.75	19,000	99.5	19,100	
Potassium	60/80	0.44/0.58	13,400/13,700	99.3/99.3	13,500/13,800	134	0.80	16,600	99.4	16,700	
Trace Cations:											
Strontium	9.3/9.6	23.3/24.0	31/30	77.5/75.0	40/40	9.6	5.03	181	94.8	191	
Lead	2.6/4.0	3.82/7.84	65/47	95.6/92.2	68/51	2.9	8.79	30	90.9	33	
Cobalt	0.3/0.4	9.10/16.7	3/2	90.9/83.3	3.3/2.4	0.5	7.70	6	92.3	6.5	
Nickel	0.3/0.4	9.10/16.7	3/2	90.9/83.3	3.3/2.4	0.5	2.86	17	97.1	17.5	
Zinc	0.3/L 0.4	0.79/-	38/33	99.2/100	38/33	1.0	2.13	46	97.9	47	

TABLE 4.5 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N2

Location	Gunnar Main					Gunnar Main					Gunnar Main
Depth from Surface	7.6 to 8.2 m					12.2 m					19.0 m
Parent Material	Reddish brown, silty, sand tailings					Organic silt, medium plastic, grey					Clay, medium to highly plastic, grey
Field Code	N2E (S10)					N2E (S14)					N2E (S16)
Date	85.03.21					85.03.21					
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	
Chromium	0.3/0.8	1.11/3.33	27/23	98.9/95.8	27/24	0.5	1.35	37	98.7	37	
Copper	L 0.3/0.8	-/5.80	15/13	100/94.2	15/13.8	L 0.5	-	12	100	12	
Cadmium	L 0.3/L 0.4	-/-	L 2/L 2	-/-	-/-	L 0.5	-	L 2	-	-	
Barium	2.6/3.6	1.12/1.54	230/230	98.7/98.3	233/234	4.3	0.95	450	99.1	454	
Vanadium	0.5/0.6	1.06/1.40	47/42	98.9/97.8	47/43	0.5	1.14	44	98.9	44	
Titanium	5.1/6.4	0.36/0.48	1,410/1,330	99.3/99.3	1,420/1,340	7.2	0.36	1,980	99.5	1,990	
Arsenic	0.1/0.2	1.37/2.41	7.2/8.1	98.6/97.6	7.3/8.3	0.1	2.33	4.2	97.7	4.3	
Selenium	L 0.02/L 0.02	-/-	L 0.1/L 0.1	-/-	-/-	0.02	9.09	0.2	90.9	0.22	
Molybdenum	1.0/1.2	100/100	L 2/L 2	-/-	1.0/1.2	1.0	100	L 2	-	1.0	
Beryllium	L 0.2/L 0.2	-/-	2/4	100/100	2/4	0.2	16.7	1	83.3	1.2	
Total Sulphur (%)											
Sum Anions											
Sum Cations											
Radionuclides											
Uranium (ug/g)	-	-	-	-	60	-	-	-	-	45	6.4
Thorium-230 (Bq/g)	-	-	-	-	4.5	-	-	-	-	3.0	-
Radium-226 (Bq/g)	-	-	-	-	7.5	-	-	-	-	6.0	0.55
Lead-210 (Bq/g)	-	-	-	-	7.0	-	-	-	-	5.0	0.70
Polonium-210 (Bq/g)	-	-	-	-	4.0	-	-	-	-	4.5	0.50
Radium-228 (Bq/g)	-	-	-	-	-	-	-	-	-	-	-
Thorium-232 (Bq/g)	-	-	-	-	0.30	-	-	-	-	0.25	-
Thorium-228 (Bq/g)	-	-	-	-	0.30	-	-	-	-	0.25	-
LOI %											

TABLE 4.6 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN AT N2 HUMMOCK

Location	Gunnar Main at N2 Hummock					Gunnar Main at N2 on Hummock				
Depth from Surface	0 to 2 cm					45 cm				
Parent Material	Sand, loose reddish brown tailings					Sand, loose reddish brown tailings				
Field Code										
Date	85.06.24					85.06.24				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter										
pH of Leach Water										
IC Scan (Anions):										
Bromide	L 125	-	-	-	L 125	L 36	-	-	-	L 36
Chloride	875	-	-	-	875	137	-	-	-	137
Fluoride	L 25	-	-	-	L 25	L 7	-	-	-	L 7
O-Phosphate	L 250	-	-	-	L 250	L 72	-	-	-	L 72
Sulphate	159,000	-	-	-	159,000	18,700	-	-	-	18,700
Nitrate	L 25	-	-	-	L 25	L 7	-	-	-	L 7
Major Cations:										
Magnesium	3,650	19.6	15,000	80.6	18,600	432	4.95	8,300	95.1	8,730
Calcium	85,000	96.2	3,410	3.86	88,400	8,570	89.0	1,060	11.0	9,630
Iron	80	0.26	30,300	99.7	30,400	338	1.82	18,300	98.4	18,600
Manganese	5	2.29	213	97.7	218	4.3	2.89	145	97.3	149
Silica	6,250	1.50	412,000	98.6	418,000	1,250	0.20	615,000	99.8	616,000
Aluminum	1,180	1.84	62,800	98.1	64,000	259	0.33	79,300	99.6	79,600
Sodium	2,130	6.61	30,100	93.4	32,200	259	0.56	45,600	99.6	45,800
Potassium	280	3.83	7,040	96.2	7,320	70	0.75	9,270	99.2	9,340
Trace Cations:										
Strontium	173	81.6	39	18.3	212	8.6	22.1	31	79.5	39
Lead	13	9.15	130	91.5	142	13.7	20.4	53	79.1	67
Cobalt	L 3	-	7	100	7	1.4	31.8	3	68.2	4.4
Nickel	L 3	-	10	100	10	1.4	13.5	9	86.5	10.4
Zinc	7.5	15.3	41	83.7	49	14	28.6	35	71.4	49

TABLE 4.6 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN AT N2 HUMMOCK

Location	Gunnar Main at N2 Hummock					Gunnar Main at N2 on Hummock				
Depth from Surface	0 to 2 cm					45 cm				
Parent Material	Sand, loose reddish brown tailings					Sand, loose reddish brown tailings				
Field Code										
Date	85.06.24					85.06.24				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	2.5	7.81	29	90.1	32	1.4	6.09	22	95.7	23
Copper	L 3	-	26	100	26	3.6	9.73	33	89.2	37
Cadmium	5.0	100	L 2	-	5.0	0.7	100	L 2	-	0.7
Barium	63	18.7	274	81.3	337	8.6	4.30	191	95.5	200
Vanadium	6.3	12.9	43	87.8	49	1.1	4.58	23	95.8	24
Titanium	70	3.22	2,100	96.8	2,170	11.5	0.74	1,540	99.3	1,550
Arsenic	3.8	20.2	15	78.8	18.8	1.7	10.2	15	89.8	16.7
Selenium	-	-	-	-	-	-	-	-	-	-
Molybdenum	10	100	L 2	-	10	2.9	100	L 2	-	2.9
Beryllium	L 1	-	3	100	3	L 1	-	2	100	2
Total Sulphur (%)										
Sum Anions										
Sum Cations										
Radionuclides										
Uranium (ug/g)										
Thorium-230 (Bq/g)										
Radium-226 (Bq/g)										
Lead-210 (Bq/g)										
Polonium-210 (Bq/g)										
Radium-228 (Bq/g)										
LOI %										

TABLE 4.6 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN AT N2 ON HUMMOCK

Location	Gunnar Main at N2 on Hummock
Depth from Surface	104 cm on ice
Parent Material	Sand, reddish brown tailings
Field Code	
Date	85.06.24

	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter					
pH of Leach Water					
IC Scan (Anions):					
Bromide	L 56	-	-	-	L 56
Chloride	233	-	-	-	233
Fluoride	L 11	-	-	-	L 11
O-Phosphate	L 111	-	-	-	L 111
Sulphate	111,000	-	-	-	111,000
Nitrate	L 11	-	-	-	L 11
Major Cations:					
Magnesium	1,710	9.66	16,000	90.4	17,700
Calcium	45,500	90.8	4,610	9.20	50,100
Iron	1,410	4.15	32,600	95.9	34,000
Manganese	61	17.2	293	82.8	354
Silica	6,100	1.11	542,000	98.9	548,000
Aluminum	1,210	1.47	81,300	98.5	82,500
Sodium	1,020	2.38	41,800	97.7	42,800
Potassium	255	2.79	8,880	97.2	9,140
Trace Cations:					
Strontium	50	51.0	48	49.0	98
Lead	38	22.4	132	77.6	170
Cobalt	3.3	29.2	8	70.8	11.3
Nickel	2.2	14.5	13	85.5	15.2
Zinc	3.3	5.24	60	95.2	63

TABLE 4.6 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN AT N2 ON HUMMOCK

Location	Gunnar Main at N2 on Hummock				
Depth from Surface	104 cm on ice				
Parent Material	Sand, reddish brown tailings				
Field Code					
Date	85.06.24				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	4.4	11.3	35	89.7	39
Copper	2.2	6.88	30	93.7	32
Cadmium	3.3	100	L 2	-	3.3
Barium	30	6.82	410	93.2	440
Vanadium	3.9	8.86	40	90.9	44
Titanium	4.4	0.20	2,170	98.2	2,210
Arsenic	4.2	15.0	24	85.7	28
Selenium	-	-	-	-	-
Molybdenum	4.4	100	L 2	-	4.4
Beryllium	L 0.6	-	2	100	2
Total Sulphur (%)					
Sum Anions					
Sum Cations					
Radionuclides					
Uranium (ug/g)					
Thorium-230 (Bq/g)					
Radium-226 (Bq/g)					
Lead-210 (Bq/g)					
Polonium-210 (Bq/g)					
Radium-228 (Bq/g)					
LOI %					

TABLE 4.7 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N3

Location	Outlet Gunnar Main						
Depth from Surface	1.5 to 2.1 m						
Parent Material	Sand, silty, reddish brown tailings						
Field Code	N3E (S3A)						
Date	84.12.06						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter							
pH of Leach Water	6.2/6.1	-	-	-	-	-	-
IC Scan (Anions):							
Bromide	L 18/L 20	-	-	-	-	-	L 18/L 20
Chloride	190/230	-	-	-	-	-	190/230
Fluoride	8.5/8.4	-	-	-	-	-	8.5/8.4
O-Phosphate	L 18/L 20	-	-	-	-	-	L 18/L 20
Sulphate	37,000/42,000	-	-	-	-	-	37,000/42,000
Nitrate	L 18/L 20	-	-	-	-	-	L 18/L 20
Major Cations:							
Magnesium	540/520	3.21/2.89	16,000/17,200	95.2/95.6	250/270	1.49/1.50	16,800/18,000
Calcium	13,000/16,000	92.9/93.0	480/610	3.43/3.55	540/530	3.86/3.08	14,000/17,200
Iron	4.8/5.2	0.02/0.02	21,000/23,000	93.3/95.4	1,470/1,130	6.53/4.69	22,500/24,100
Manganese	18.9/19.0	7.16/6.64	240/260	90.9/90.9	5/7	1.89/2.45	264/286
Silica SiO_2	260/250	0.04/0.04	710/1,130	0.12/0.19	580,000	99.8	581,000
Aluminum	18/24	0.03/0.03	11,800/12,600	16.4/13.9	60,000/78,000	83.6/86.1	71,800/90,600
Sodium	330/350	0.64/0.51	380/910	0.74/1.31	51,000/68,000	98.7/98.1	51,700/69,300
Potassium	59/52	0.84/0.51	930/2,100	13.3/20.6	6,000/8,000	85.7/78.4	7,000/10,200
Trace Cations:							
Strontium	15/18	32.6/33.3	9.3/11.7	20.2/21.7	22/24	47.8/44.4	46/54
Lead	4.8/10.9	2.06/4.21	198/230	85.0/88.8	31/18	13.3/6.95	233/259
Cobalt	0.4/0.8	7.14/8.42	5.2/5.7	92.9/60.0	L 1/3	-/31.6	5.6/9.5
Nickel	0.7/0.8	5.93/8.42	7.1/7.7	60.2/81.0	4/1	33.9/10.5	11.8/9.5
Zinc	0.4/0.8	1.14/2.29	32/33	91.4/94.3	3/1	8.57/2.86	35/35
Chromium	1.8/1.2	5.00/3.24	26/28	72.2/75.7	8/8	22.2/21.6	36/37

TABLE 4.7 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N3

Location				Outlet Gunnar Main			
Depth from Surface				1.5 to 2.1 m			
Parent Material				Sand, silty, reddish brown tailings			
Field Code				N3E (S3A)			
Date				84.12.06			
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Copper	0.7/1.2	2.69/3.87	20/23	76.9/74.2	5/7	19.2/22.6	26/31
Cadmium	L 0.4/L 0.4	-	5.6/6.6	100/100	L 2/L 2	-	5.6/6.6
Barium	3.0/2.8	1.09/0.87	220/260	79.7/80.8	53/59	19.2/18.3	276/322
Vanadium	0.92/1.01	2.24/2.66	27/30	65.8/78.9	13/7	31.7/18.4	41/38
Titanium	7.4/8.1	0.60/0.54	106/123	8.55/8.20	1,130/1,370	91.1/91.3	1,240/1,500
Arsenic	0.15/0.32	1.10/2.16	13.4/14.5	98.5/98.0	-	-	13.6/14.8
Selenium	L 0.02	-	0.35/0.61	100/100	-	-	0.35/0.61
Molybdenum	3.0/3.2	48.4/43.8	3.2/4.1	51.6/56.2	L 2/L 2	-	6.2/7.3
Beryllium	L 0.18/L 0.20	-	2.6/3.0	72.2/75.0	1/1	27.8/25.0	3.6/4.0
Total Sulphur (%)	-	-	-	-	-	-	L 0.01
Total Carbonate (%)	-	-	-	-	-	-	L 0.01
Sum Anions	328	-	-	-	-	-	-
Sum Cations	786	-	-	-	-	-	-
Radionuclides							
Uranium (ug/g)							
Thorium-230 (Bq/g)							
Radium-226 (Bq/g)							
Lead-210 (Bq/g)							
Polonium-210 (Bq/g)							
Radium-228 (Bq/g)							
LOI %							1.4

TABLE 4.7 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N3

Location	Outlet Gunnar Main							Outlet Gunnar Main		
Depth from Surface	4.3 to 4.6 m							8.2 to 8.8m		
Parent Material	Sand, silty, reddish brown tailing, organic							Clay, silty, low to medium plastic, grey		
Field Code	N3E (S5A)							N3E (S10B) (SRC Data)		
Date	84.12.06							84.12.02		
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	Acid Leach (ug/g)	Total (ug/g)
Parameter										
pH of Leach Water	7.0	-	-	-	-	-	-			
IC Scan (Anions):										
Bromide	L 17	-	-	-	-	-	L 17			
Chloride	59	-	-	-	-	-	59			
Fluoride	6.2	-	-	-	-	-	6.2			
O-Phosphate	L 17	-	-	-	-	-	L 17			
Sulphate	1,790	-	-	-	-	-	1,790			
Nitrate	L 17	-	-	-	-	-	L 17			
Major Cations:										
Magnesium	162	1.71	6,900	72.6	2,400	25.3	9,500			
Calcium	500	6.12	3,500	43.2	4,100	50.6	8,100			
Iron	24	0.12	17,300	83.6	3,400	16.4	20,700			
Manganese	5.9	1.60	310	84.0	53	14.4	369			
Silica SiO_2	540	0.08	520	0.08	680,000	99.8	681,000			
Aluminum	17	0.03	16,600	26.1	47,000	73.9	63,600			
Sodium	48	0.38	600	4.80	11,900	95.2	12,500			
Potassium	148	0.66	4,300	19.2	18,000	80.4	22,400			
Trace Cations:										
Strontium	3.4	1.44	63	26.7	170	72.0	236			
Lead	1.7	3.21	24	45.3	27	50.9	53			
Cobalt	0.7	7.37	7.8	82.1	1	10.5	9.5			
Nickel	1.0	1.56	16.1	64.1	8	32.0	25			
Zinc	1.7	3.76	29	45.2	10	24.4	41			
Chromium	1.7	2.20	35	77.4	18	32.7	55			

TABLE 4.7 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N3

Location	Outlet Gunnar Main							Outlet Gunnar Main		
Depth from Surface	4.3 to 4.6 m							8.2 to 8.8m		
Parent Material	Sand, silty, reddish brown tailing, organic							Clay, silty, low to medium plastic, grey		
Field Code	N3E (S5A)							N3E (S10B) (SRC Data)		
Date	84.12.06							84.12.02		
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	Acid Leach (ug/g)	Total (ug/g)
Copper	2.0	15.9	10.6	84.1	L 1	-	12.6			
Cadmium	0.3	5.45	5.2	94.5	L 2	-	5.5			
Barium	8.6	2.58	84	25.2	240	72.1	333			
Vanadium	1.38	3.00	28	60.9	17	37.0	46			
Titanium	31	1.11	660	23.7	2,100	75.3	2,790			
Arsenic	0.17	12.4	1.20	87.6	-	-	1.37			
Selenium	L 0.02	-	0.03	100	-	-	0.03			
Molybdenum	0.34	10.0	3.1	91.2	L 2	-	3.4			
Beryllium	L 0.17	-	0.92	47.9	1	52.1	1.92			
Total Sulphur (%)	-	-	-	-	-	-	L 0.01			
Total Carbonate (%)	-	-	-	-	-	-	0.08			
Sum Anions	39	-	-	-	-	-	-			
Sum Cations	46	-	-	-	-	-	-			
Radionuclides										
Uranium (ug/g)	0.00001	0.0002	2.6	52	-	-	5.0	L 0.00001	2.6	5.0
Thorium-230 (Bq/g)	0.0001	0.03	0.25	83	-	-	0.3	L 0.0001	0.25	0.30
Radium-226 (Bq/g)	0.001	0.17	.40	67	-	-	0.6	0.001	0.40	0.60
Lead-210 (Bq/g)	0.001	0.2	0.4	80	-	-	0.5	0.001	0.40	0.50
Polonium-210 (Bq/g)	0.0001	0.02	0.3	60	-	-	0.5	L 0.0001	0.30	0.50
Radium-228 (Bq/g)	0.0001	0.06	0.05	31	-	-	0.16	0.0001	0.05	0.16
LOI %							1.6			

TABLE 4.8 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL N4

Location	Gunnar Central							Gunnar Central						
Depth from Surface	1.5 to 2.1 m							5.2 to 5.8 m						
Parent Material	Silt, reddish brown tailings							Clay, low plastic, light grey						
Field Code	N4A (S2A)							N4A (S5A)						
Date	84.12.07							84.12.07						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter														
pH of Leach Water	5.1	-	-	-	-	-	-	6.6	-	-	-	-	-	-
IC Scan (Anions):														
Bromide	L 44	-	-	-	-	-	L 44	L 18	-	-	-	-	-	L 18
Chloride	400	-	-	-	-	-	400	18	-	-	-	-	-	18
Fluoride	7.0	-	-	-	-	-	7.0	14	-	-	-	-	-	14
O-Phosphate	L 44	-	-	-	-	-	L 44	L 18	-	-	-	-	-	L 18
Sulphate	109,000	-	-	-	-	-	109,000	1,450	-	-	-	-	-	1,450
Nitrate	L 44	-	-	-	-	-	L 44	L 18	-	-	-	-	-	L 18
Major Cations:														
Magnesium	1,350	6.78	18,300	92.0	240	1.21	19,900	137	1.20	8,700	76.3	2,600	22.8	11,400
Calcium	38,000	98.2	500	1.29	188	0.66	38,700	400	3.60	5,000	45.0	5,700	51.4	11,100
Iron	11.4	0.04	26,000	97.0	770	2.87	26,800	5.6	0.02	24,000	85.7	4,000	14.3	28,000
Manganese	52	15.1	290	84.1	3	0.87	345	3.0	0.60	430	85.7	69	13.8	502
Silica SiO_2	520	0.10	730	0.15	500,000	99.8	501,000	635	0.09	350	0.05	670,000	99.9	671,000
Aluminum	87	0.11	14,800	18.1	67,000	81.8	81,900	3.7	0.005	19,300	26.3	54,000	73.7	73,300
Sodium	790	1.38	570	0.99	56,000	97.6	57,400	18.5	0.10	910	4.69	18,500	95.4	19,400
Potassium	52	0.57	1,300	14.4	7,700	85.1	9,050	197	0.67	5,300	18.0	24,000	81.4	29,500
Trace Cations:														
Strontium	46	61.3	11.2	14.9	18	24.0	75	2.8	0.97	69	23.8	220	75.9	290
Lead	53	12.0	390	88.0	L 2	-	443	3.0	8.82	31	91.2	L 2	-	34
Cobalt	0.9	12.9	6.1	87.1	L 1	-	7.0	0.7	5.55	11.9	94.4	L 1	-	12.6
Nickel	1.7	17.3	8.1	82.7	L 1	-	9.8	2.2	1.41	23	14.7	140	89.7	156
Zinc	0.9	1.91	44	93.6	2	4.26	47	2.2	3.86	47	82.5	8	14.0	57
Chromium	2.6	6.84	30	79.0	5	13.2	38	2.2	2.72	48	59.3	31	38.3	81

TABLE 4.8 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL N4

Location	Gunnar Central							Gunnar Central						
Depth from Surface	1.5 to 2.1 m							5.2 to 5.8 m						
Parent Material	Silt, reddish brown tailings							Clay, low plastic, light grey						
Field Code	N4A (S2A)							N4A (S5A)						
Date	84.12.07							84.12.07						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Copper	1.7	3.62	40	85.1	5	10.6	47	2.6	14.8	14	79.5	1	5.68	17.6
Cadmium	L 0.9	-	6.8	100	L 2	-	6.8	0.4	5.55	6.8	94.4	L 2	-	7.2
Barium	5.2	1.10	420	89.0	47	9.96	472	17.8	31.8	153	27.3	390	69.6	560
Vanadium	2.6	5.91	34	77.3	7	15.9	44	1.7	17.3	40	9.83	24	36.4	66
Titanium	22	1.08	121	5.96	1,890	93.1	2,030	48	1.42	1,240	36.8	2,080	61.7	3,370
Arsenic	0.17	2.02	8.2	97.6	-	-	8.4	0.26	8.67	2.7	90.0	-	-	3.0
Selenium	L 0.04	-	0.43	100	-	-	0.43	L 0.02	-	0.24	100	-	-	0.24
Molybdenum	7.9	68.1	3.7	31.9	L 2	-	11.6	0.4	7.02	5.3	93.0	L 2	-	5.7
Beryllium	L 0.44	-	3.4	77.3	1	22.7	4.4	L 0.19	-	0.96	49.0	1	51.0	1.96
Total Sulphur (%)	-	-	-	-	-	-	L 0.01	-	-	-	-	-	-	L 0.01
Total Carbonate (%)	-	-	-	-	-	-	L 0.01	-	-	-	-	-	-	0.01
Sum Anions	2,280	-	-	-	-	-	-	31	-	-	-	-	-	-
Sum Cations	2,050	-	-	-	-	-	-	38	-	-	-	-	-	-
Radionuclides														
Uranium (ug/g)	0.0018	0.004	15	33	-	-	45//15	-	-	-	-	-	-	-
Thorium-230 (Bq/g)	0.0061	0.07	8.5	100	-	-	8.5//8.5	-	-	-	-	-	-	-
Radium-226 (Bq/g)	0.0426	0.2	9.0	45	-	-	20//9.0	-	-	-	-	-	-	-
Lead-210 (Bq/g)	0.1564	0.87	18	100	-	-	18//18	-	-	-	-	-	-	-
Polonium-210 (Bq/g)	0.0165	0.15	14	100	-	-	11//14	-	-	-	-	-	-	-
Radium-228 (Bq/g)	0.0011	0.37	.10	33	-	-	0.3//0.10	-	-	-	-	-	-	-
LOI %							2.2							2.1

TABLE 4.8 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL N4

Location	Gunnar Central	Gunnar Central
Depth from Surface	3.1 to 3.7 m	4.0 m
Parent Material	Clay, low plastic, light grey	Clay, low to medium plastic, grey
Field Code	N4B (S2)	GC5A (S4)
Date	84.12.07	85.03.21

	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter							
pH of Leach Water	7.4/7.3	-	-	-	-	-	-
IC Scan (Anions):							
Bromide	L 14	-	-	-	-	-	L 14
Chloride	10.4/13.2	-	-	-	-	-	10.4/13.2
Fluoride	7.2/8.6	-	-	-	-	-	7.2/8.6
O-Phosphate	6/3	-	-	-	-	-	6/3
Sulphate	121/125	-	-	-	-	-	121/125
Nitrate	12/14	-	-	-	-	-	12/14
Major Cations:							
Magnesium	890/860	7.42/7.17	7,900/8,000	65.8/66.7	3,200/3,100	26.7/25.8	12,000/12,000
Calcium	410/410	3.90/3.90	4,900/4,900	46.7/46.7	5,200/5,200	49.5/49.5	10,500/10,500
Iron	4,500/3,200	14.5/11.1	23,000/22,000	74.0/76.1	3,600/3,700	11.6/12.8	31,100/28,900
Manganese	47/32	9.33/6.69	390/380	77.4/79.5	67/66	13.3/13.8	504/478
Silica SiO_2	19,300/20,000	3.16/3.08	310/260	0.05/0.04	590,000/630,000	96.7/96.9	610,000/650,000
Aluminum	6,000/4,200	7.89/5.38	15,000/17,800	19.7/22.8	55,000/56,000	72.4/71.8	76,000/78,000
Sodium	240/230	1.04/1.09	850/830	3.68/3.93	22,000/20,000	95.2/94.8	23,100/21,100
Potassium	1,500/1,610	4.62/4.94	3,000/3,000	9.23/9.20	28,000/28,000	86.2/85.9	32,500/32,600
Trace Cations:							
Strontium	4.9/5.0	1.57/1.71	67/67	21.5/22.9	240/220	76.9/75.3	312/292
Lead	5.2/6.8	19.3/24.3	22/21	81.5/75.0	L 2/L 2	-	27/28
Cobalt	2.3/2.5	14.7/18.8	11.3/10.8	72.4/81.2	2/L 1	6.67/-	15.6/13.3
Nickel	5.2/5.4	17.3/20.0	22/21	73.3/77.8	3/1	4.78/1.75	30/27
Zinc	10.4/5.4	17.3/9.64	45/44	75.0/78.6	7/7	11.7/12.5	60/56
Chromium	8.6/10.4	12.1/15.8	44/40	62.0/60.6	18/16	25.4/24.2	71/66

TABLE 4.8 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL N4

Location	Gunnar Central							Gunnar Central
Depth from Surface	3.1 to 3.7 m							4.0 m
Parent Material	Clay, low plastic, light grey							Clay, low to medium plastic, grey
Field Code	N4B (S2)							GC5A (S4)
Date	84.12.07							85.03.21
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Total (ug/g)
Copper	6.0/7.1	23.1/35.5	12.2/11.3	46.9/56.5	8/2	30.8/10.0	26/20	
Cadmium	3.2/3.2	34.4/35.6	6.1/5.7	65.6/63.3	L 2/L 2	-	9.3/9.0	
Barium	58/65	9.52/11.0	131/124	21.5/21.0	420/400	69.0/67.0	609/589	
Vanadium	5.0/5.2	7.58/8.39	37/36	56.1/58.1	24/21	36.4/33.9	66/62	
Titanium	200/193	7.72/5.59	1,230/1,220	34.3/35.4	2,160/2,040	60.2/59.1	3,590/3,450	
Arsenic	0.46/0.39	27.7/28.05	1.2/1.0	72.3/71.9	-	-	1.66/1.39	
Selenium	L 0.01/L 0.02	-	0.015/0.016	100/100	-	-	0.015/0.016	
Molybdenum	0.6/0.7	10.3/11.9	5.2/5.2	89.7/88.1	L 2/L 2	-	5.8/5.9	
Beryllium	0.14/0.18	7.14/18.0	0.82/0.82	41.8/82.0	1/L 1	51.0/-	1.96/1.00	
Total Sulphur (%)	-	-	-	-	-	-	L 0.01	
Total Carbonate (%)	-	-	-	-	-	-	0.01	
Sum Anions	3.3	-	-	-	-	-	-	
Sum Cations	916	-	-	-	-	-	-	
Radionuclides								
Uranium (ug/g)	-	-	-	-	-	-	-	5.1
Thorium-230 (Bq/g)	-	-	-	-	-	-	-	-
Radium-226 (Bq/g)	-	-	-	-	-	-	-	0.50
Lead-210 (Bq/g)	-	-	-	-	-	-	-	0.45
Polonium-210 (Bq/g)	-	-	-	-	-	-	-	0.35
Radium-228 (Bq/g)	-	-	-	-	-	-	-	-
LOI %							1.9	

TABLE 4.9 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N6

Location	Gunnar Main					Gunnar Main	Gunnar Main					Gunnar Main
Depth from Surface	1.5 to 1.9 m						6.1 to 6.7 m					5.0 to 7.0 m
Parent Material	Silty sand, reddish brown tailings					Clay, medium plastic, dark green	Clay, silty, grey					Sand, silty, reddish brown tailings
Field Code	N6A (S2)					N6A (S4)	N6A (S5)					GM9A (S1)
Date	85.03.09						85.03.09					
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)		Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	
Parameter												
pH of Leach Water												
IC Scan (Anions):												
Bromide	L 11	-	-	-	L 11		L 1	-	-	-	L 1	
Chloride	118	-	-	-	118		29	-	-	-	29	
Fluoride	5.6	-	-	-	5.6		1.2	-	-	-	1.2	
O-Phosphate	L 56	-	-	-	L 56		L 5	-	-	-	L 5	
Sulphate	11,800	-	-	-	11,800		480	-	-	-	480	
Nitrate	L 2	-	-	-	L 2		0.2	-	-	-	0.2	
Major Cations:												
Magnesium	302	1.91	15,500	98.1	15,800		298	3.18	9,100	96.8	9,400	
Calcium	18,500	91.1	1,800	8.87	20,300		218	1.86	11,500	98.3	11,700	
Iron	48	0.22	21,500	99.8	21,500		449	1.91	23,000	98.3	23,400	
Manganese	29	12.2	210	88.2	238		12	3.41	340	96.6	352	
Silica SiO_2	269	0.04	540,000	100	540,000		1,460	0.22	670,000	99.9	671,000	
Aluminum	36	0.05	79,000	100	79,000		864	0.14	59,000	98.5	59,900	
Sodium	274	0.54	50,000	99.4	50,300		86	0.60	14,300	99.3	14,400	
Potassium	55	0.75	7,300	99.1	7,360		389	0.18	21,000	98.1	21,400	
Trace Cations:												
Strontium	18	32.7	37	67.3	55		2.4	0.92	260	99.2	262	
Lead	6.7	5.6	112	94.1	119		1.0	5.88	16	94.1	17.0	
Cobalt	1.1	18.0	5	82.0	6.1		0.2	2.17	9	97.8	9.2	
Nickel	0.6	7.89	6	78.9	7.6		0.5	2.5	20	97.5	20	
Zinc	0.6	1.54	38	97.4	39		3.4	6.66	48	94.1	51	

TABLE 4.9 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN N6

Location	Gunnar Main					Gunnar Main	Gunnar Main					Gunnar Main
Depth from Surface	1.5 to 1.9 m						6.1 to 6.7 m					5.0 to 7.0 m
Parent Material	Silty sand, reddish brown tailings					Clay, medium plastic, dark green	Clay, silty, grey					Sand, silty, reddish brown tailings
Field Code	N6A (S2)					N6A (S4)	N6A (S5)					GM9A (S1)
Date	85.03.09						85.03.09					
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)		Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	
Chromium	1.1	5.0	21	95.5	22		0.7	1.56	44	97.8	45	
Copper	0.6	1.76	33	97.1	34		1.0	7.70	12	92.3	13.0	
Cadmium	L 0.6	-	L 2	-	-		L 0.2	-	L 2	-	-	
Barium	5.0	1.85	270	98.2	275		9.1	1.45	620	98.6	629	
Vanadium	0.8	1.95	40	97.6	41		1.6	3.14	49	96.1	51	
Titanium	7.8	0.51	1,520	99.3	1,530		20	0.74	2,700	99.3	2,720	
Arsenic	0.06	0.54	11	99.5	11.1		0.1	6.67	1.4	93.3	1.5	
Selenium	0.03	13.0	0.2	87.0	0.23		0.01	100	L 0.1	-	0.01	
Molybdenum	2.2	100	L 2	-	2.2		L 0.2	-	L 2	-	-	
Beryllium	0.3	15.0	2	85.0	2.3		0.1	9.09	1	90.9	1.1	
Total Sulphur (%)												
Sum Anions												
Sum Cations												
Radionuclides												
Uranium (ug/g)	-	-	-	-	55	11	-	-	-	-	4.0	53
Thorium-230 (Bq/g)	-	-	-	-	6.0	-	-	-	-	-	0.13	-
Radium-226 (Bq/g)	-	-	-	-	13	2.0	-	-	-	-	0.20	7.5
Lead-210 (Bq/g)	-	-	-	-	12	2.5	-	-	-	-	0.15	8.0
Polonium-210 (Bq/g)	-	-	-	-	7.0	2.5	-	-	-	-	0.12	8.0
Radium-228 (Bq/g)	-	-	-	-	-	-	-	-	-	-	-	-
Thorium-232 (Bq/g)	-	-	-	-	0.55	-	-	-	-	-	0.07	-
Thorium-228 (Bq/g)	-	-	-	-	0.55	-	-	-	-	-	0.07	-
LOI %												

TABLE 4.10 TAILINGS SOLIDS ANALYSIS, EAST OF BERM OFF GUNNAR MAIN

Location	East of Berm off Gunnar Main					East of Berm off Gunnar Main				
Depth from Surface	90 cm					10 cm				
Parent Material	Reddish brown tailings overlying organic soil					Reddish brown, sandy, silty tailings				
Field Code										
Date	85.06.24					85.06.24				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter										
pH of Leach Water										
IC Scan (Anions):										
Bromide	L 35	-	-	-	L 35	L 170	-	-	-	L 170
Chloride	133	-	-	-	133	289	-	-	-	289
Fluoride	4.2	-	-	-	4.2	34	-	-	-	34
O-Phosphate	L 64	-	-	-	L 64	L 34	-	-	-	L 34
Sulphate	58,100	-	-	-	58,100	177,000	-	-	-	177,000
Nitrate	L 7	-	-	-	L 7	L 34	-	-	-	L 34
Major Cations:										
Magnesium	350	2.15	15,900	97.5	16,300	3,090	14.9	17,600	85.0	20,700
Calcium	23,600	90.4	2,550	9.8	26,100	65,300	96.0	2,710	3.99	68,000
Iron	371	1.19	30,700	98.7	31,100	2,280	6.70	31,700	93.2	34,000
Manganese	5.6	2.49	219	97.3	225	27	6.57	384	93.4	411
Silica	2,030	0.34	576,000	97.0	594,000	11,600	3.04	371,000	97.1	382,000
Aluminium	406	0.46	88,800	99.6	89,200	2,450	3.91	60,100	96.0	62,600
Sodium	441	0.75	58,300	99.3	58,700	1,560	5.98	25,000	94.0	26,600
Potassium	90	0.93	9,600	99.1	9,690	619	7.61	7,510	92.4	8,130
Trace Cations:										
Strontium	23	32.9	47	67.1	70	109	72.2	42	27.8	151
Lead	21	12.0	154	88.0	175	68	29.3	164	70.7	232
Cobalt	2.1	23.0	7	76.9	9.1	6.8	28.3	17	70.8	24
Nickel	1.4	5.38	25	96.1	26	6.8	32.4	14	66.7	21
Zinc	L 0.7	-	87	100	87	4,180	98.8	50	1.18	4,230

TABLE 4.10 TAILINGS SOLIDS ANALYSIS, EAST OF BERM OFF GUNNAR MAIN

Location	East of Berm off Gunnar Main					East of Berm off Gunnar Main				
Depth from Surface	90 cm					10 cm				
Parent Material	Reddish brown tailings overlying organic soil					Reddish brown, sandy, silty tailings				
Field Code										
Date	85.06.24					85.06.24				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	2.8	9.33	27	90.0	30	6.8	17.0	33	82.5	40
Copper	1.4	4.67	28	93.3	30	6.8	23.4	22	75.9	29
Cadmium	L 0.7	-	L 2	-	-	3.4	100	L 2	-	3.4
Barium	18	4.42	389	95.6	407	92	19.5	381	80.5	473
Vanadium	2.1	3.50	58	96.7	60	6.8	12.8	46	86.8	53
Titanium	21	1.17	1,800	98.9	1,820	75	3.30	2,200	96.9	2,270
Arsenic	0.8	4.49	17	95.5	17.8	5.1	18.2	23	82.1	28
Selenium	0.04	10.0	0.4	90.0	0.4	-	-	-	-	-
Molybdenum	5.6	73.7	2	26.3	7.6	10	100	L 2	-	10
Beryllium	0.4	11.8	3	88.2	3.4	L 2	-	3	100	3
Total Sulphur (%)										
Sum Anions										
Sum Cations										
Radionuclides										
Uranium (ug/g)										
Thorium-230 (Bq/g)										
Radium-226 (Bq/g)										
Lead-210 (Bq/g)										
Polonium-210 (Bq/g)										
Radium-228 (Bq/g)										
LOI %										

TABLE 4.11 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN IN FROG POND

Location	Below Gunnar Main in Frog Pond					Below Gunnar Main in Frog Pond				
Depth from Surface	75 cm					85 cm				
Parent Material	Reddish brown, silty, sandy tailings just above organic layer					Organic layer just under reddish brown tailings				
Field Code	GM-21					GM-21				
Date	85.06.24					85.06.24				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter										
pH of Leach Water										
IC Scan (Anions):										
Bromide	L 24/L 24	-	-	-	L 24/L 24	3.5	-	-	-	3.5
Chloride	67/19	-	-	-	67/19	98	-	-	-	98
Fluoride	2.9/2.9	-	-	-	2.9/2.9	11	-	-	-	11
O-Phosphate	L 48/L 48	-	-	-	L 48/L 48	L 7	-	-	-	L 7
Sulphate	32,600/31,200	-	-	-	32,600/31,200	20,300	-	-	-	20,300
Nitrate	L 5/L 5	-	-	-	L 5/L 5	2.8	-	-	-	2.8
Major Cations:										
Magnesium	125/115	1.24/1.15	10,100/9,950	99.0/99.9	10,200/9,960	651	45.5	783	54.8	1,430
Calcium	12,700/13,400	93.4/94.4	899/838	6.61/5.90	13,600/14,200	7,770	63.7	4,380	36.0	12,200
Iron	20/25	0.10/0.13	19,990/19,300	99.9/99.9	20,000/19,300	11	0.45	2,430	99.6	2,440
Manganese	1.9/1.9	1.37/1.38	137/136	98.6/98.6	139/138	16	36.3	28	63.5	44.1
Silica	298/269	0.06/0.05	532,000/544,000	99.8/99.9	533,000/544,000	518	0.39	131,000	99.2	132,000
Aluminum	49/52	0.06/0.06	84,900/84,200	99.9/99.9	85,000/84,300	154	0.82	18,600	99.5	18,700
Sodium	182/182	0.31/0.32	58,000/56,600	99.7/99.8	58,200/56,700	207	13.0	1,380	86.8	1,590
Potassium	17/18	0.17/0.18	10,200/10,100	99.8/99.8	10,200/10,100	25	0.83	2,990	99.3	3,010
Trace Cations:										
Strontium	14/15	29.8/34.1	33/29	70.2/65.9	47/44	12	24.5	37	75.5	49
Lead	11/12	21.2/72.2	41/42	78.8/77.8	52/54	4.9	100	L 2	-	4.9
Cobalt	1.4/1.4	26.0/26.0	4/4	74.0/74.0	5.4/5.4	1.4	25.9	4	74.1	5.4
Nickel	L 0.5/0.5	-/7.69	8/6	100/92.3	8/6.5	L 0.7	-	14	100	14
Zinc	L 0.5/L 0.5	-/-	41/30	100/100	41/30	L 0.7	-	14	100	14

TABLE 4.11 TAILINGS SOLIDS ANALYSIS, GUNNAR MAIN IN FROG POND

Location	Below Gunnar Main in Frog Pond					Below Gunnar Main in Frog Pond				
Depth from Surface	75 cm					85 cm				
Parent Material	Reddish brown, silty, sandy tailings just above organic layer					Organic layer just under reddish brown tailings				
Field Code	GM-21					GM-21				
Date	85.06.24					85.06.24				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	1.0/1.0	4.55/4.55	21/21	95.5/95.5	22/22	1.4	12.3	10	87.7	11.4
Copper	1.0/1.0	6.25/7.14	15/13	93.8/92.9	16.0/14.0	1.4	9.72	13	90.3	14.4
Cadmium	L 0.5/L 0.5	-/-	L 2/L 2	-/-	-/-	L 0.7	-	L 2	-	-
Barium	5/5	1.95/2.27	251/215	98.0/97.7	256/220	2.8	3.04	89	96.7	92
Vanadium	1.0/1.0	1.92/2.22	51/44	98.0/97.8	52/45	0.7	5.11	13	94.9	13.7
Titanium	7.2/7.7	0.47/0.56	1,530/1,360	99.4/99.3	1,540/1,370	4.9	1.30	371	98.7	376
Arsenic	0.1/0.1	0.66/0.62	15/16	99.3/99.4	15.1/16.1	0.07	5.11	1.3	94.9	1.37
Selenium	L 0.02/L 0.02	-/-	0.4/0.4	100/100	0.4/0.4	0.04	100	L 0.1	-	0.04
Molybdenum	3.4/3.4	63.0/100	2/L 2	37.0/-	5.4/3.4	2.1	100	L 2	-	2.1
Beryllium	L 0.2/L 0.2	-/-	2/2	100/100	2/2	0.3	23.1	1	76.9	1.3
Total Sulphur (%)										
Sum Anions										
Sum Cations										
Radionuclides										
Uranium (ug/g)	-	-	-	-	45.4	-	-	-	-	26.9
Thorium-230 (Bq/g)	-	-	-	-	8.0	-	-	-	-	0.80
Radium-226 (Bq/g)	-	-	-	-	13	-	-	-	-	0.45
Lead-210 (Bq/g)	-	-	-	-	10	-	-	-	-	1.3
Polonium-210 (Bq/g)	-	-	-	-	-	-	-	-	-	-
Radium-228 (Bq/g)	-	-	-	-	0.25	-	-	-	-	L 0.08
Thorium-232 (Bq/g)	-	-	-	-	1.4	-	-	-	-	0.14
Thorium-228 (Bq/g)	-	-	-	-	1.4	-	-	-	-	0.70
LOI %										

TABLE 4.12 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL - GC5

Location	Gunnar Central					Gunnar Central				
Depth from Surface	1.8 to 2.1m					2.2m				
Parent Material	Reddish brown, tailings (tube sample)					Reddish brown, tailings (tube sample)				
Field Code	GC5 (S2T)					GC5 (S2T)				
Date	85.03.23					85.03.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter										
pH of Leach Water										
IC Scan (Anions):										
Bromide	L 44	-	-	-	L 44	L 26	-	-	-	L 26
Chloride	88	-	-	-	88	256	-	-	-	256
Fluoride	4.4	-	-	-	4.4	5.1	-	-	-	5.1
O-Phosphate	L 176	-	-	-	L 176	L 64	-	-	-	L 64
Sulphate	95,900	-	-	-	95,900	39,700	-	-	-	39,700
Nitrate	L 4	-	-	-	L 4	L 4	-	-	-	L 4
Major Cations:										
Magnesium	757	2.54	29,000	97.3	29,800	1,870	13.5	12,000	86.3	13,900
Calcium	41,400	95.3	2,000	4.61	43,400	17,400	68.0	8,200	32.0	25,600
Iron	308	0.92	33,000	99.1	33,300	237	1.22	19,200	98.8	19,400
Manganese	27	8.65	285	91.3	312	95	33.9	185	66.1	280
Silica	2,640	0.60	440,000	99.3	443,000	2,300	0.47	490,000	99.5	492,000
Aluminum	440	0.58	76,000	99.5	76,400	1,110	1.88	58,000	98.1	59,100
Sodium	642	1.62	39,000	98.5	39,600	512	2.50	20,000	97.5	20,500
Potassium	202	1.63	12,200	98.4	12,400	461	2.99	14,900	96.8	15,400
Trace Cations:										
Strontium	56	51.3	53	48.6	109	31	17.7	144	82.3	175
Lead	44	8.73	460	91.3	504	10	12.7	69	87.3	79
Cobalt	2.6	24.5	8	75.5	10.6	1.3	24.5	4	75.5	5.3
Nickel	3.5	30.4	8	69.6	11.5	1.3	7.98	15	92.0	16.3
Zinc	2.6	4.13	60	95.2	63	3.8	8.64	40	90.9	44

TABLE 4.12 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL - GC5

Location			Gunnar Central					Gunnar Central		
Depth from Surface			1.8 to 2.1m					2.2m		
Parent Material			Reddish brown, tailings (tube sample)					Reddish brown, tailings (tube sample)		
Field Code			GC5 (S2T)					GC5 (S2T)		
Date			85.03.23					85.03.23		
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	4.4	10.2	39	90.7	43	1.3	4.06	31	96.8	32
Copper	L 0.9	-	25	100	25	1.3	5.42	23	95.8	24
Cadmium	0.9	100	L 2	-	0.9	L 1.3	-	L 2	-	-
Barium	11	2.43	440	97.6	451	14	3.23	420	96.8	434
Vanadium	2.2	2.93	73	97.3	75	2.6	5.00	49	94.2	52
Titanium	25	1.08	2,300	99.1	2,320	27	1.33	2,000	98.5	2,030
Arsenic	2.7	9.64	25	89.3	28	0.90	9.47	8.6	90.5	9.5
Selenium	0.09	8.26	1.0	91.7	1.09	0.06	10.7	0.5	89.3	0.56
Molybdenum	5.3	100	L 2	-	5.3	3.8	100	L 2	-	3.8
Beryllium	0.4	7.41	5	92.6	5.4	0.6	23.1	2	76.9	2.6
Total Sulphur (%)										
Sum Anions										
Sum Cations										
Radionuclides										
Uranium (ug/g)	-	-	-	-	77	-	-	-	-	49
Thorium-230 (Bq/g)	-	-	-	-	25	-	-	-	-	8.0
Radium-226 (Bq/g)	-	-	-	-	50	-	-	-	-	9.5
Lead-210 (Bq/g)	-	-	-	-	40	-	-	-	-	7.0
Polonium-210 (Bq/g)	-	-	-	-	50	-	-	-	-	10.0
Radium-228 (Bq/g)	-	-	-	-	-	-	-	-	-	-
Thorium-232 (Bq/g)	-	-	-	-	1.2	-	-	-	-	0.45
Thorium-228 (Bq/g)	-	-	-	-	1.2	-	-	-	-	0.45
LOI %										

TABLE 4.12 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL - GC5

Location			Gunnar Central		
Depth from Surface			2.2 to 2.3m		
Parent Material			Silty-clay underlying tailings (core sample)		
Field Code			GC5 (S2T)		
Date			85.03.23		
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter					
pH of Leach Water					
IC Scan (Anions):					
Bromide	L 2	-	-	-	L 2
Chloride	45	-	-	-	45
Fluoride	1.3	-	-	-	1.3
O-Phosphate	L 6	-	-	-	L 6
Sulphate	860	-	-	-	860
Nitrate	L 0.3	-	-	-	L 0.3
Major Cations:					
Magnesium	474	5.95	7,500	94.1	7,970
Calcium	285	3.01	9,200	97.0	9,480
Iron	864	4.94	16,600	94.9	17,500
Manganese	13	5.58	220	94.4	233
Silica	1,820	0.28	640,000	99.7	642,000
Aluminum	1,600	2.78	56,000	97.2	57,600
Sodium	134	0.92	14,500	99.3	14,600
Potassium	768	3.70	20,000	96.2	20,800
Trace Cations:					
Strontium	3.8	1.62	230	98.2	234
Lead	1.0	10.0	9	90.0	10.0
Cobalt	0.3	4.11	7	95.8	7.3
Nickel	1.3	7.98	15	92.0	16.3
Zinc	1.9	4.32	42	95.5	44

TABLE 4.12 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL - GC5

Location	Gunnar Central				
Depth from Surface	2.2 to 2.3m				
Parent Material	Silty-clay underlying tailings (core sample)				
Field Code	GC5 (S2T)				
Date	85.03.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	1.9	5.28	34	94.4	36
Copper	1.6	18.6	7	81.4	8.6
Cadmium	L 0.3	-	L 2	-	-
Barium	11.5	2.29	490	97.6	502
Vanadium	2.7	4.82	53	94.6	56
Titanium	23	0.95	2,400	99.2	2,420
Arsenic	0.2	10.0	1.83	91.5	2.0
Selenium	0.02	-	L 0.1	-	-
Molybdenum	0.3	13.0	2	87.0	2.3
Beryllium	0.2	16.7	1	83.3	1.2
Total Sulphur (%)					
Sum Anions					
Sum Cations					
Radionuclides					
Uranium (ug/g)	-	-	-	-	4
Thorium-230 (Bq/g)	-	-	-	-	0.11
Radium-226 (Bq/g)	-	-	-	-	0.20
Lead-210 (Bq/g)	-	-	-	-	0.11
Polonium-210 (Bq/g)	-	-	-	-	0.15
Radium-228 (Bq/g)	-	-	-	-	-
Thorium-232 (Bq/g)	-	-	-	-	0.06
Thorium-228 (Bq/g)	-	-	-	-	0.06
LOI %					

TABLE 4.13 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL

Location	Gunnar Central near Head of Tailings					Gunnar Central near Head of Tailings				
Depth from Surface	0 to 1 cm					20 cm				
Parent Material	White crystaline material on tailings					Sandy, reddish brown tailings				
Field Code	GC-6					GC-6				
Date	85.06.23					85.06.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter										
pH of Leach Water										
IC Scan (Anions):										
Bromide	L 740	-	-	-	L 740	L 52	-	-	-	L 52
Chloride	746/735	-	-	-	746/735	196	-	-	-	196
Fluoride	L 148	-	-	-	L 148	L 10	-	-	-	L 10
O-Phosphate	L 1,480	-	-	-	L 1,480	L 103	-	-	-	L 103
Sulphate	253,000/235,000	-	-	-	253,000/235,000	60,800	-	-	-	60,800
Nitrate	L 148	-	-	-	L 148	L 10	-	-	-	L 10
Major Cations:										
Magnesium	2,150/1,610	36.9/29.8	3,670/3,810	63.1/70.6	5,820/5,400	731	5.76	12,000	94.5	12,700
Calcium	89,500/97,000	93.9/97.0	5,800/3,020	6.09/3.02	95,300/100,000	23,700	94.0	1,540	6.11	25,200
Iron	1,310/485	15.2/5.72	7,310/8,000	84.8/94.3	8,620/8,480	30	0.10	29,000	99.9	29,000
Manganese	104/29	64.1/32.2	58/61	35.8/67.8	162/90	16	8.12	180	91.4	197
Silica	7,300/2,940	2.35/0.98	303,000/294,000	97.7/98.0	310,000/300,000	165	0.03	579,000	99.9	579,000
Aluminum	910/323	2.29/0.83	38,900/38,500	97.7/99.2	39,800/38,800	47	0.06	79,200	99.9	79,200
Sodium	2,090/1,760	8.67/7.39	22,000/22,000	91.3/92.4	24,100/23,800	494	1.05	41,700	88.5	47,100
Potassium	417/250	8.00/4.87	4,800/4,880	92.0/95.1	5,220/5,130	25	0.26	9,590	99.8	9,610
Trace Cations:										
Strontium	209/235	87.8/91.0	29/23	12.2/8.91	238/258	28	43.8	36	56.3	64
Lead	89/74	80.9/77.0	21/22	19.0/22.9	110.96	14	11.1	112	88.9	126
Cobalt	L 15/L 15	-/-	1/1	100/100	1/1	2.1	25.9	6	74.1	8.1
Nickel	L 15/L 15	-/-	5/6	100/100	5/6	2.1	14.9	12	85.1	14.1
Zinc	L 15/15	-/45.0	16/18	100/54.5	16/33	7.2	14.1	44	86.3	51

TABLE 4.13 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL

Location	Gunnar Central near Head of Tailings					Gunnar Central near Head of Tailings				
Depth from Surface	0 to 1 cm					20 cm				
Parent Material	White crystaline material on tailings					Sandy, reddish brown tailings				
Field Code	GC-6					GC-6				
Date	85.06.23					85.06.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	15/15	57.7/53.6	11/13	42.3/46.4	26/28	2.1	6.18	32	94.1	34
Copper	L 15/L 15	-/-	16/16	100/100	16/16	L 1	-	39	97.5	40
Cadmium	30/29	100/-	L 2/L 2	-/-	30/29	1.0	100	L 2	-	1.0
Barium	30/29	27.0/25.9	81/83	73.0/74.1	111/112	6.2	2.28	266	97.8	272
Vanadium	L 8/L 8	-/-	12/13	100/100	12/13	1.0	2.5	39	97.5	40
Titanium	75/59	10.2/7.54	658/724	89.9/92.4	732/783	12	0.54	2,230	99.6	2,240
Arsenic	L 2/L 2	-/-	16/14	100/100	16/14	L 0.1	-	16	100	16
Selenium	-	-	-	-	-	-	-	-	-	-
Molybdenum	15/15	100/100	L 2/L 2	-/-	15/15	3.1	100	L 2	-	3.1
Beryllium	L 8/L 8	-/-	1/1	100/100	1/1	L 0.5	-	3	100	3
Total Sulphur (%)										
Sum Anions										
Sum Cations										
Radionuclides										
Uranium (ug/g)										
Thorium-230 (Bq/g)										
Radium-226 (Bq/g)										
Lead-210 (Bq/g)										
Polonium-210 (Bq/g)										
Radium-228 (Bq/g)										
LOI %										

TABLE 4.13 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL

Location	Gunnar Central Between Head of Tailings and Standing Water					Gunnar Central near Standing Water				
Depth from Surface	0.0 to 0.1 cm					0.0 to 0.1 cm				
Parent Material	White salt crust on surface of tailings and standing water					White salt crust on surface of tailings				
Field Code	GC-7					GC-8				
Date	85.06.23					85.06.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter										
pH of Leach Water										
IC Scan (Anions):										
Bromide	L 64	-	-	-	L 64	L 44	-	-	-	L 44
Chloride	2,050	-	-	-	2,050	2,330	-	-	-	2,330
Fluoride	38	-	-	-	38	44	-	-	-	44
O-Phosphate	192	-	-	-	192	L 44	-	-	-	L 44
Sulphate	39,000	-	-	-	39,000	114,000	-	-	-	114,000
Nitrate	L 19	-	-	-	L 19	L 18	-	-	-	L 18
Major Cations:										
Magnesium	3,520	40.2	5,240	59.8	8,760	24,200	79.1	6,420	21.0	30,600
Calcium	4,480	81.3	1,030	18.7	5,510	4,580	76.3	1,420	23.7	6,000
Iron	160	1.58	9,960	98.6	10,100	163	1.12	14,300	98.6	14,500
Manganese	685	89.4	81	10.6	766	616	85.4	105	14.6	721
Silica	742	1.75	42,300	99.8	42,400	730	0.14	517,000	99.8	518,000
Aluminum	250	0.42	59,200	99.5	59,500	198	0.27	71,900	99.7	72,100
Sodium	2,560	5.87	41,100	94.3	43,600	2,380	4.63	49,000	95.3	51,400
Potassium	62	0.78	7,940	99.3	8,000	49	0.52	9,410	99.5	9,460
Trace Cations:										
Strontium	52	66.7	26	33.3	78	52.8	65.2	28	34.6	81
Lead	14	43.8	18	56.3	32	17	27.0	46	73.0	63
Cobalt	6.4	86.5	1	13.5	7.4	6.2	67.4	3	32.6	9.2
Nickel	16	69.6	7	30.4	23	11	64.8	6	35.3	17.0
Zinc	11	18.3	49	81.7	60	7.0	22.6	24	77.4	31

TABLE 4.13 TAILINGS SOLIDS ANALYSIS, GUNNAR CENTRAL

Location	Gunnar Central Between Head of Tailings and Standing Water					Gunnar Central near Standing Water				
Depth from Surface	0.0 to 0.1 cm					0.0 to 0.1 cm				
Parent Material	White salt crust on surface of tailings and standing water					White salt crust on surface of tailings				
Field Code	GC-7					GC-8				
Date	85.06.23					85.06.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	2.6	20.6	10	79.4	12.6	1.8	10.0	16	88.9	18
Copper	3.2	14.5	19	86.4	22	3.5	13.5	22	84.6	26
Cadmium	0.6	100	L 1	-	0.6	L 0.9	-	L 2	-	-
Barium	3.8	0.35	104	96.3	108	3.5	3.07	111	97.4	114
Vanadium	1.0	3.03	32	97.0	33	0.9	3.21	27	96.4	28
Titanium	7.7	0.92	827	99.0	835	6.2	0.66	933	99.4	93.9
Arsenic	0.3	0.45	6.4	95.5	6.7	0.4	5.00	7.6	95.0	8.0
Selenium	L 0.03	-	0.3	100	0.3	0.04	16.7	0.2	83.3	0.24
Molybdenum	2.6	100	L 2	-	2.6	2.6	100	L 2	-	2.6
Beryllium	0.3	23.1	1	76.9	1.3	0.4	16.7	2	83.3	2.4
Total Sulphur (%)										
Sum Anions										
Sum Cations										
Radionuclides										
Uranium (ug/g)										
Thorium-230 (Bq/g)										
Radium-226 (Bq/g)										
Lead-210 (Bq/g)										
Polonium-210 (Bq/g)										
Radium-228 (Bq/g)										
LOI %										

TABLE 4.14 TAILINGS SOLIDS ANALYSIS, LANGLEY BAY N5

Location	Langley Bay							Langley Bay						
Depth from Surface	2.1 to 2.7 m							3 to 3.7 m						
Parent Material	Silt, reddish brown tailings							Silt, reddish brown tailings, organic						
Field Code	N5A (S3A)							N5A (S4A)						
Date	84.12.08							84.12.07						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter														
pH of Leach Water	5.1							4.8						
IC Scan (Anions):														
Bromide	L 54	-	-	-	-	-	L 54	L 30	-	-	-	-	-	L 30
Chloride	290	-	-	-	-	-	290	133	-	-	-	-	-	133
Fluoride	16.2	-	-	-	-	-	16.2	9.0	-	-	-	-	-	9.0
O-Phosphate	L 54	-	-	-	-	-	L 54	L 30	-	-	-	-	-	L 30
Sulphate	152,000	-	-	-	-	-	152,000	46,000/ 46,000	-	-	-	-	-	46,000/ 46,000
Nitrate	L 54	-	-	-	-	-	L 54	L 30	-	-	-	-	-	L 30
Major Cations:														
Magnesium	560	1.75	31,000	96.9	420	1.31	32,000	610	2.54	22,000	91.7	1,400	5.83	24,000
Calcium	49,000	98.4	780	1.57	65	0.13	49,000	15,000	79.4	2,000	10.6	1,900	10.1	18,900
Iron	53	0.12	43,000	96.2	1,600	3.58	44,700	14	0.03	39,000	93.3	2,800	6.70	41,800
Manganese	23	4.20	520	94.9	5	0.91	548	58	12.0	400	82.5	27	5.57	485
Silica SiO_2	880	0.18	1,870	0.38	490,000	99.4	493,000	700	0.12	700	0.12	590,000	99.8	591,000
Aluminum	125	0.15	23,000	28.0	59,000	71.9	82,100	42	0.05	24,000	28.9	59,000	71.1	83,000
Sodium	830	1.57	1,010	1.91	51,000	96.6	52,800	370	10.5	950	2.69	34,000	96.3	35,300
Potassium	108	1.22	1,430	16.2	7,300	82.6	8,840	157	0.79	4,300	21.7	15,300	77.3	19,800
Trace Cations:														
Strontium	54	62.8	20	23.3	12	14.0	86	24	14.4	45	27.0	98	58.7	167
Lead	31	7.49	360	87.0	23	5.56	414	7.8	4.73	131	79.4	26	15.8	165
Cobalt	1.1	8.80	10.4	83.2	1	8.0	12.5	1.8	11.0	9.5	58.3	5	30.7	16.3
Nickel	2.2	12.6	14.3	81.7	1	5.71	17.5	1.8	7.83	18.3	79.6	3	13.0	23
Zinc	1.1	1.80	56	91.8	4	6.56	61	1.2	2.40	84.0	82.4	7	14.0	50

TABLE 4.14 TAILINGS SOLIDS ANALYSIS, LANGLEY BAY N5

Location	Langley Bay							Langley Bay						
Depth from Surface	2.1 to 2.7 m							3 to 3.7 m						
Parent Material	Silt, reddish brown tailings							Silt, reddish brown tailings, organic						
Field Code	N5A (S3A)							N5A (S4A) -						
Date	84.12.08							84.12.07						
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	3.3	6.88	38	79.2	7	14.6	48	1.2	1.97	41	67.2	19	31.2	61
Copper	4.3	6.94	56	90.3	2	3.23	62	2.4	9.60	22	88.0	1	4.0	25
Cadmium	L 1.1	-	13.6	100	L 2	-	13.6	L 0.6	-	7.2	100	L 2	-	7.2
Barium	6.5	1.14	530	92.7	35	6.12	572	7.2	1.05	500	72.7	181	26.3	688
Vanadium	3.2	5.33	53	88.3	4	6.67	60	1.5	1.00	140	93.3	8	5.33	150
Titanium	27	0.97	230	8.24	2,530	90.7	2,790	9.0	0.31	470	15.9	2,470	83.7	2,950
Arsenic	0.33	2.68	12	97.6	-	-	12.3	1.02	2.13	47	97.9	-	-	48
Selenium	0.05	9.26	0.49	90.7	-	-	0.54	L 0.03	-	0.36	100	-	-	0.36
Molybdenum	9.8	62.0	6.0	37.9	L 2	-	15.8	4.2	36.5	7.3	63.5	L 2	-	11.5
Beryllium	L 0.54	-	4.5	81.8	1	18.2	5.5	L 0.30	-	3.8	100	L 1	-	3.8
Total Sulphur (%)	-	-	-	-	-	-	L 0.01	-	-	-	-	-	-	L 0.01
Total Carbonate (%)	-	-	-	-	-	-	L 0.01	-	-	-	-	-	-	0.01
Sum Anions	3,170	-	-	-	-	-	-	961	-	-	-	-	-	-
Sum Cations	2,550	-	-	-	-	-	-	824	-	-	-	-	-	-
Radionuclides														
Uranium (ug/g)	0.0039	0.005	31	38	-	-	82//25	-	-	-	-	-	-	-
Thorium-230 (Bq/g)	0.0021	0.014	8.5	57	-	-	13//8.5	-	-	-	-	-	-	-
Radium-226 (Bq/g)	0.0264	0.075	7.5	21	-	-	33//7.5	-	-	-	-	-	-	-
Lead-210 (Bq/g)	0.7209	1.8	25	63	-	-	40//25	-	-	-	-	-	-	-
Polonium-210 (Bq/g)	0.0177	0.07	14	56	-	-	25//14	-	-	-	-	-	-	-
Radium-228 (Bq/g)	0.0016	0.4	.11	28	-	-	0.4//0.11	-	-	-	-	-	-	-
LOI %							3.4							5.7

TABLE 4.14 TAILINGS SOLIDS ANALYSIS, LANGLEY BAY N5

Location	Langley Bay							Langley Bay	Langley Bay	Langley Bay	Langley Bay	Langley Bay
Depth from Surface	12.2 to 12.8 m							2.5 m	0.9 m	2.4 m	4.0 m	5.5 m
Parent Material	Clay, medium plastic, medium grey							Silt, tailings	Sand, silty tailings	Sand-Silt tailings	Organic Clay	Clay, grey
Field Code	N5A (SIIA)							LB2A (S4)	LB3A (S2)	LB3B (S1)	LB3B (S2)	LB3B (S4)
Date	84.12.08							85.03.24	85.03.25	85.03.25	85.03.25	85.03.25
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Total (ug/g)	Total (ug/g)	Total (ug/g)	Total (ug/g)	Total (ug/g)
Parameter												
pH of Leach Water	6.9											
IC Scan (Anions):												
Bromide-	L 15	-	-	-	-	-	L 15					
Chloride	56	-	-	-	-	-	56					
Fluoride	3.5	-	-	-	-	-	3.5					
O-Phosphate	L 15	-	-	-	-	-	L 15					
Sulphate	22,000/22,000	-	-	-	-	-	22,000/22,000					
Nitrate	L 15	-	-	-	-	-	L 15					
Major Cations:												
Magnesium	270	1.93	10,800	77.1	2,900	20.7	14,000					
Calcium	7,600	55.1	3,100	22.5	3,100	22.5	13,800					
Iron	7.6	0.03	22,000	85.3	3,800	14.7	25,800					
Manganese	23	5.58	340	82.5	49	11.9	412					
Silica SiO_2	310	0.05	380	0.06	670,000	99.9	671,000					
Aluminum	20	0.03	14,800	20.9	56,000	79.1	70,800					
Sodium	167	0.46	580	1.58	36,000	98.1	36,700					
Potassium	111	0.50	240	1.07	22,000	98.2	22,400					
Trace Cations:												
Strontium	12.3	5.86	47	22.4	151	71.9	210					
Lead	2.0	0.29	670	96.0	26	3.72	698					
Cobalt	0.6	3.80	9.2	58.2	6	38.0	15.8					
Nickel	0.3	1.25	14.8	61.7	9	37.5	24					
Zinc	L 0.3	-	45	86.5	7	13.5	52					

TABLE 4.14 TAILINGS SOLIDS ANALYSIS, LANGLEY BAY N5

Location	Langley Bay							Langley Bay	Langley Bay	Langley Bay	Langley Bay	Langley Bay
Depth from Surface	12.2 to 12.8 m							2.5 m	0.9 m	2.4 m	4.0 m	5.5 m
Parent Material	Clay, medium plastic, medium grey							Silt tailings	Sand, silty tailings	Sand-Silt tailings	Organic Clay	Clay, grey
Field Code	N5A (SIIA)							LB2A (S4)	LB3A (S2)	LB3B (S1)	LB3B (S2)	LB3B (S4)
Date	84.12.08							85.03.24	85.03.25	85.03.25	85.03.25	85.03.25
	Water Leach (ug/g)	% of Total	Acid Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Total (ug/g)	Total (ug/g)	Total (ug/g)	Total (ug/g)	Total (ug/g)
Chromium	1.2	1.40	60	69.8	25	29.1	86					
Copper	0.9	1.29	66	94.3	3	4.29	70					
Cadmium	L 0.3	-	11.7	100	L 2	-	11.7					
Barium	2.6	0.65	187	46.8	210	52.5	400					
Vanadium	0.59	1.09	34	63.0	19	35.2	54					
Titanium	4.4	0.16	540	20.1	2,150	79.9	2,690					
Arsenic	0.06	1.09	5.4	98.2	-	-	5.5					
Selenium	L 0.01	-	0.12	100	-	-	0.12					
Molybdenum	1.76	27.1	4.7	72.3	L 2	-	6.5					
Beryllium	L 0.15	-	1.76	100	L 1	-	1.76					
Total Sulphur (%)	-	-	-	-	-	-	L 0.01					
Total Carbonate (%)	-	-	-	-	-	-	0.01					
Sum Anions	449	-	-	-	-	-	-					
Sum Cations	414	-	-	-	-	-	-					
Radionuclides												
Uranium (ug/g)	-	-	-	-	-	-	-	65	46	39	12	4.7
Thorium-230 (Bq/g)	-	-	-	-	-	-	-	-	-	-	-	-
Radium-226 (Bq/g)	-	-	-	-	-	-	-	45	13	9.0	0.85	0.75
Lead-210 (Bq/g)	-	-	-	-	-	-	-	40	13	11	1.0	0.7
Polonium-210 (Bq/g)	-	-	-	-	-	-	-	35	9.0	9.0	1.0	0.7
Radium-228 (Bq/g)	-	-	-	-	-	-	-	-	-	-	-	-
LOI %							2.0					

TABLE 4.15 TAILINGS SOLIDS ANALYSIS, LANGLEY BAY - LB7A

Location			Langley Bay			Langley Bay	Langley Bay
Depth from Surface			0.0 to 0.3 m			1.2 m	4.0 m
Parent Material			Silt, sandy reddish brown tailings			Sand, silty tailings	Clay, grey
Field Code			LB7A (S1)			LB7A (S2)	LB7A (S6)
Date			85.03.25			85.03.25	85.03.25
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Total (ug/g)	Total (ug/g)
Parameter							
pH of Leach Water							
IC Scan (Anions):							
Bromide	L 2	-	-	-	L 2		
Chloride	78	-	-	-	78		
Fluoride	2.4	-	-	-	2.4		
O-Phosphate	L 10	-	-	-	L 10		
Sulphate	5,400	-	-	-	5,400		
Nitrate	1.9	-	-	-	1.9		
Major Cations:							
Magnesium	326/324	1.40/1.66	23,000/19,200	98.7/98.5	23,300/19,500		
Calcium	1,820/2,860	52.3/64.0	1,660/1,610	47.7/36.0	3,480/4,470		
Iron	67/60	0.23/0.23	29,000/26,000	99.7/99.7	29,100/26,100		
Manganese	0.7/1.0	0.24/0.45	290/220	99.7/99.7	291/221		
Silica	432/456	0.07/0.07	620,000/620,000	99.9/99.9	620,000/620,000		
Aluminum	74/89	0.08/0.10	89,000/90,000	99.9/99.9	89,100/90,100		
Sodium	103/118	0.17/0.21	59,000/56,000	99.9/99.9	59,100/56,100		
Potassium	40/43	0.38/0.44	10,400/9,700	99.6/99.6	10,400/9,740		
Trace Cations:							
Strontium	2.9/3.6	6.4/8.0	42/41	93.3/91.1	45/45		
Lead	1.9/2.4	1.17/1.59	160/150	98.8/98.7	162/152		
Cobalt	L 0.2/0.2	-/4.76	7/4	100/95.2	7/4.2		
Nickel	L 0.2/L 0.2	-/-	11/8	100/100	11/8		
Zinc	L 0.2/0.2	-/0.43	53/47	100/99.6	53/47		

TABLE 4.15 TAILINGS SOLIDS ANALYSIS, LANGLEY BAY - LB7A

Location	Langley Bay					Langley Bay	Langley Bay
Depth from Surface	0.0 to 0.3 m					1.2 m	4.0 m
Parent Material	Silt, sandy reddish brown tailings					Sand, silty tailings	Clay, grey
Field Code	LB7A (S1)					LB7A (S2)	LB7A (S6)
Date	85.03.25					85.03.25	85.03.25
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Total (ug/g)	Total (ug/g)
Chromium	0.2/0.5	0.60/1.85	33/27	98.4/98.2	33/27		
Copper	0.7/0.5	1.79/1.56	38/32	97.4/98.4	39/32		
Cadmium	L 0.2/L 0.2	-/-	L 2/L 2	-/-	-/-		
Barium	3.1/3.6	0.85/0.99	360/360	99.2/98.9	363/364		
Vanadium	0.1/0.2	0.20/0.43	50/47	99.8/99.6	50/47		
Titanium	2.6/3.8	0.13/0.21	1,960/1,790	99.9/99.8	1,960/1,790		
Arsenic	0.2/0.2	1.05/0.95	19/21	98.9/99.0	19/21		
Selenium	0.01/0.01	0.02/0.02	0.4/0.5	97.6/98.0	0.41/0.51		
Molybdenum	0.2/0.5	9.0/100	2/L 2	90.9/-	2.2/0.5		
Beryllium	L 0.1/L 0.1	-/-	2/2	100/100	2/2		
Total Sulphur (%)							
Sum Anions							
Sum Cations							
Radionuclides							
Uranium (ug/g)	-	-	-	-	51	40	4.4
Thorium-230 (Bq/g)	-	-	-	-	7.0	-	-
Radium-226 (Bq/g)	-	-	-	-	15	13	0.60
Lead-210 (Bq/g)	-	-	-	-	15	14	0.55
Polonium-210 (Bq/g)	-	-	-	-	8.0	11	0.50
Radium-228 (Bq/g)	-	-	-	-	-	-	-
Thorium-232 (Bq/g)	-	-	-	-	0.65	-	-
Thorium-228 (Bq/g)	-	-	-	-	0.65	-	-
LOI %							

4.4.6 Rare Earth Test Results

Rare earth testing was conducted on 2 samples. One sample referred to as "sand" was taken from the mound near Nest No. 2. The second sample, referred to as "slime" was taken from near the edge of the water in the vicinity of Piezometer GM7. The following table presents the results of the analysis.

TABLE 4.16
RARE EARTH ANALYSIS (ppm)

Symbol	Element	Sand	Slime
Y	Yttrium	18	42
La	Lanthanium	81.2	114
Cc	Cerium	131	236
Pr	Praseodymium	18	34
Nd	Neodymium	36	89
Sm	Samarium	6.23	15.9
Eu	Europium	0.38	0.90
Gd	Gadolinium	5	14
Tb	Terbium	0.4	1.4
Ho	Holmium	1.5	3.0
Er	Erbium	2.0	5.0
Tm	Thulium	0.5	1.0
Yb	Ytterbium	3.06	5.86
Lu	Lutetium	L0.13	L0.17
Au	Gold	L16*	20*

* - Parts Per Billion

L - Less Than

4.5 DISCUSSION OF RESULTS

4.5.1 Stratigraphy

The general stratigraphy encountered in the test holes was as follows:

- tailings
- organic materials
- lacustrine clayey silts and silty clays
- bedrock

The tailings were typically reddish brown in color and were easily distinguishable by it. The underlying clayey silts and silty clays were typically light to dark grey with very little weathering noted. The organic materials were black or greenish black in color.

At some locations, the organic layer was entirely absent, while at others it appeared to be up to several meters thick and was composed of both peat and organic clays. At some locations, particularly Langley Bay, the interface between the tailings and underlying native soils was not distinct. Some penetration by the fine tailings into the organics and native silt seemed to have occurred.

Bedrock was defined as the point where abrupt refusal of the BQ casing occurred. No bedrock samples were recovered however, and it is possible that this refusal was obtained on a boulder lag or dense till material. It is reasonable to assume that the refusal is bedrock, however, since there is little evidence in the surrounding terrain of the presence of till or boulders.

At Gunnar Main, the depth of tailings varied from in excess of 14 m near the spigot location (N1) to 3 to 4 m at the north side of the area (GM12, GM17).

The thickness of the underlying organic materials and clay varied from 0.5 m at Test Hole No. GM12 to in excess of 9.4 m at GM3. Generally, it would be expected that the lowest bedrock surface elevations would be found in the centre of the Gunnar Main Area which corresponds roughly to the old centre of Mudford Lake. A typical cross-section through Gunnar Main is shown on Figure No. 4.11.

At Gunnar Central, the depth of tailings was 3 to 4 m with bedrock encountered in two test holes (N4A and GC5A) at 5.8 to 9.8 m. The thickness of organic material and clay was therefore indicated to be about 6.0 m in the central portion of the area.

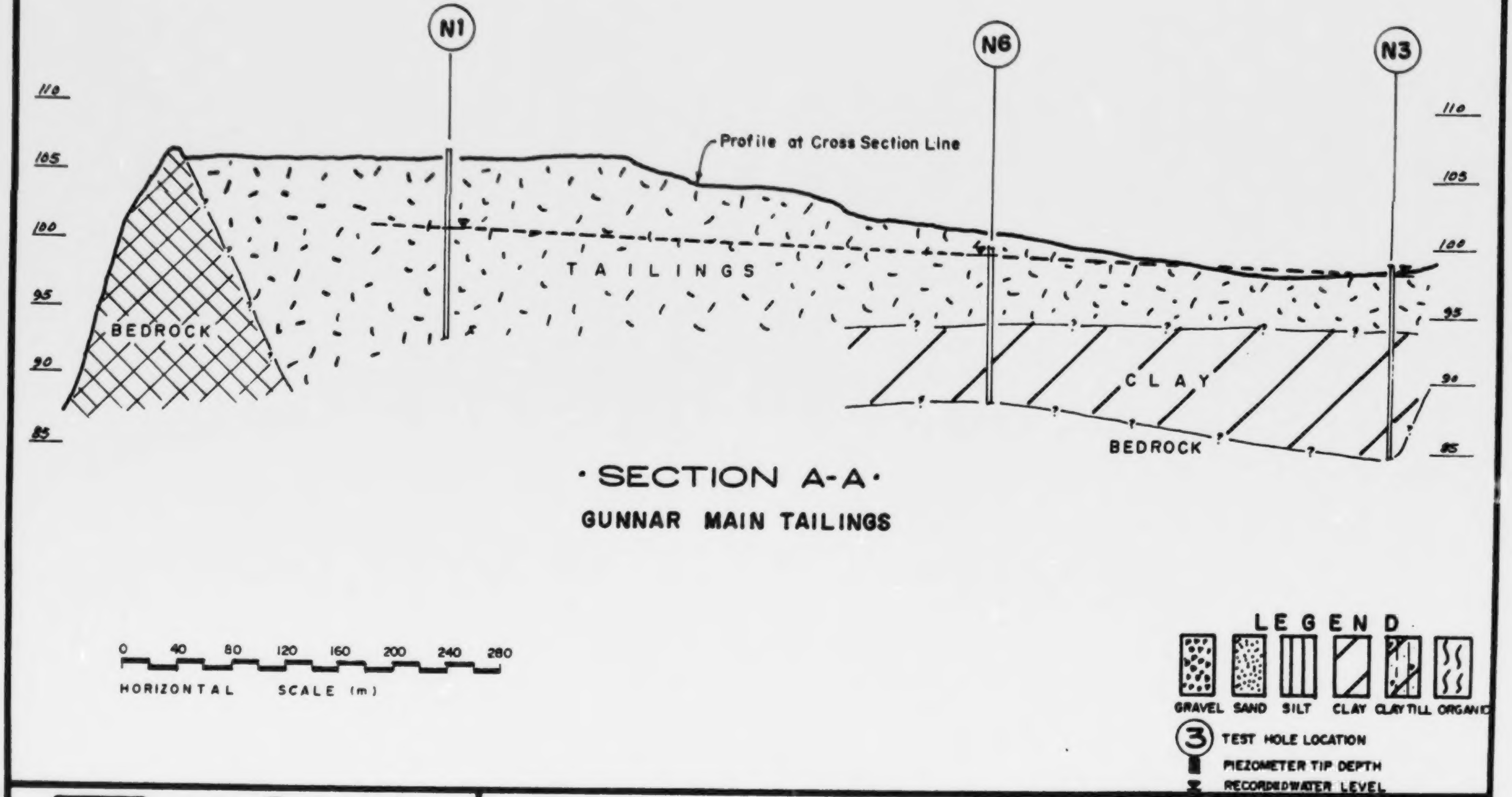
In Langley Bay, tailings depths of 2.1 to 3.7 m were encountered with the underlying clay extending to a depth in excess of 19.8 m at one location (LB2). Further to the east it appeared that the clay was 8 to 10 m thick with the bedrock encountered at a depth of 11.3 to 13 m.

In the area surrounding the Waste Rock Pile, very thin surface organic material was found over silty, grey, varved clays.

4.5.2 Geotechnical Soil Properties

The tailings graded from a fine to medium, poorly graded sand near the spigot location on Gunnar Main, to silty sand, to silt, to silty clay with increasing distance from the spigot. There was also a tendency for increasing fineness with depth. Gunnar Main was primarily poorly graded (SP) sand at the south side grading to silty sand and silt at the north side. Gunnar Central was predominantly silty sand and silt. The Langley Bay Tailings were predominantly silt and silty clay with only minor amounts of silty sand.

The moisture content values varied widely depending on the texture of the material and its position with respect to the water table. In many cases, however, the insitu moisture content was above the liquid limit implying very sensitive and weak materials.


N1
N6
N3
110
105
100
95
90
85
Profile at Cross Section Line
TAILINGS
BEDROCK
CLAY
BEDROCK
0 40 80 120 160 200 240 280
HORIZONTAL SCALE (m)
LEGEND
GRAVEL
SAND
SILT
CLAY
CLAYTILL
ORGANIC
3 TEST HOLE LOCATION
PIEZOMETER TIP DEPTH
RECORDED WATER LEVEL

·SECTION A-A·

GUNNAR MAIN TAILINGS

Geotechnical Consultants Ltd.

INTERPRETED SUBSOIL STRATIGRAPHY

NOTE: THE INFERRED SOIL STRATIFICATION HAS BEEN INTERPRETED FROM DATA OBTAINED AT TEST HOLE LOCATIONS ONLY. THE INFERRED CONTACTS SHOWN ARE BASED ON GEOLOGICAL EVIDENCE AND MAY VARY FROM THOSE SHOWN BETWEEN TEST HOLES.

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FIGURE 4.11

Density values varied from 904 to 2027 kg/m^3. Part of the variation can be attributed to variations in texture, but much of the variation is due to the test procedures used and the sensitive nature of the materials. The higher and lower values are very suspect, but it is difficult to start eliminating values without risking the integrity of the entire set of data. The potential errors reported in Section 4.3.3 should be considered when selecting appropriate density values for the tailings. The range in minimum-maximum values for the relative density tests (1037 to 2163 kg/m^3) was almost as wide as the range for the insitu values.

Permeability values for the tailings varied from 1E-03 to 1E-06 cm/sec., which appears to be a reasonable range for the texture and density of the tailings. The lower values apply to the siltier areas. The range of values also agrees well with the values determined from insitu tests.

Specific gravity values for the tailings varied from 2.60 to 2.85.

The underlying clayey silts and silty clays were generally low to medium plastic with a minor amount of highly plastic material. The moisture content values were typically 25 to 40 percent. The odd higher value probably represents a certain amount of organic material in the sample. Density values varied from 1100 to 1500 kg/m^3 with the majority of the samples in the 1200 to 1300 kg/m^3 range. More consistent values were expected since many of the density tests were with Shelby tubes and the cohesive nature of the soil reduced the effects of sample disturbance.

The permeability values for the clay varied from 1E-06 to 1E-10 cm/sec. and thus were several orders of magnitude less than the overlying tailings materials.

4.5.3 Chemical and Radionuclide Results

At the sampling locations, where piezometer intake screens were to be placed for sampling tailings porewater, tailings solids samples were also collected for chemical characterization. The concentrations in the tailings porewater is the concentration that discharges to the surface during infiltration and discharge events, and thus it is important to understand the solids chemistry which determines the porewater concentration. Three components of tailings solids were looked at in this study. The first component is the water soluble fraction which provides an indication of the readily mobilized material under continued porewater flushing. Calcium sulphate and chloride were water soluble along with a high percentage of the trace elements, strontium, cobalt, cadmium and molybdenum. This distribution undoubtedly reflects the mobilization of these particular elements during the acid leach in the milling process and their precipitation as sulphates or hydroxides in the tailings. The second component is the acid soluble component which likely reflects the fraction of the tailings material which was mobilized during the initial acid leach in the mill, but reprecipitated in the tailings in a form such as an hydroxide which is not readily water soluble at a basic pH. This inventory is expected to be more mobile under local acidic conditions.

The final residue remaining after the water soluble and acid soluble material had been analysed was the material which is locked up in an acid insoluble matrix such as fledspar or silicate mineral. This material would be considered to be relatively stable from a geochemical standpoint and only released to the environment as a result of long-term weathering processes.

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Volume

5

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VOLUME 5
APPENDIX 4

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
CONTRACT NO. 15SQ.2341-4-1674X
VOLUME 5 - APPENDIX 4
GROUNDWATER

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BBT PROJECT NO. S84-1750

MARCH 31, 1986

EXECUTIVE SUMMARY

The fieldwork for the groundwater portion of the study was conducted in conjunction with the test drilling and soil sampling for the tailings solids component. The selection of test hole locations was, therefore, made to provide the best areal coverage possible to satisfy both requirements.

The initial concept for the fieldwork as contained in the proposal was to use a track mounted auger drill mobilized by barge. The contract was not awarded until after freeze-up in late October, 1984, however, and as a result, this method of drilling had to be abandoned. In addition, the possibility for an overland winter road to be constructed to Uranium City in 1985 was uncertain and in any event, the timing would have been too late. Various types of aircraft mobilized equipment were considered in conjunction with the Scientific Authority and it was decided to use a locally available vibratory drill which could be moved by helicopter.

The vibratory drill was able to complete an adequate number of installations to satisfy the project objectives within the project budget. The disadvantages of the drill were that a complete stratigraphic log of the test holes was not possible and the type of piezometer installations was restricted. Mechanical problems with the drill affected the number of installations in some of the campaigns. Fieldwork was performed in 4 campaigns in November 1984, March 1985, June 1985 and August 1985. The vibratory drill was used for installations during the November and March campaigns only. Hand auger equipment was used for installations in June and August. In summary, 77 monitor wells were installed, with a total installed length of 284.5 m.

The monitor wells consisted of a modified Casagrande drive-point piezometer with 35 mm inside diameter riser pipes. All the monitor wells were located on Gunnar Main, Gunnar Central and Langley Bay Tailings, and along the periphery of the waste rock pile. Well tips were all installed in the tailings or the soil underlying the tailings. Wells were not installed in the Precambrian bedrock or in the areas adjacent to the tailings due to other priorities.

Monitor well locations were concentrated on the Gunnar Main Tailings since the areal extent and thickness of the tailings was much greater than the other 2 tailings areas. Because of the variation in elevation and grain size distribution, it was felt that the largest variation in porewater movement, hydraulic conductivity and geochemistry would be found in this area.

Upon installation of piezometers, water levels were monitored during each major field campaign and approximately biweekly through the winter of 1985. Because of the logistics of site visits, routine water level measurements were difficult to obtain.

Hydraulic conductivity tests were performed by carrying out response tests (slug tests) on monitor wells using Hvorslev's rising head method. The tests were performed either when the wells were initially installed or when piezometers were flushed prior to geochemical sampling.

Water samples were collected during 4 campaigns, December 1984, March 1985, June 1985 and August 1985. Two sets of samples were collected for most monitor wells, while some had 3 sets collected. Water samples were generally collected from the wells using a varistaltic pump in the winter and a stainless steel bailer in the summer. Conductivity, temperature, alkalinity, and pH of the samples were determined in the field prior to acidification and transport.

The sampling program was conducted under the direct supervision of BBT Geotechnical Consultants Ltd. The following laboratories were used for the laboratory testing program:

Chemical - IEC BEAK Consultants Ltd., Mississauga, Ontario
Radionuclides - Saskatchewan Research Council, Saskatoon, Saskatchewan
Check Tests and Replicates - Monenco Consultants Limited, Calgary, Alberta

A general overview of the water level data obtained to date shows that movement of porewater through the Gunnar Main Tailings area is from the southeast to the northwest and north. It is essentially moving from the topographic high to the topographic low and eventually discharges along the western edge of the site and moves northward via the surface water route through the outlet at the north end of the site. Water levels indicated that the depth to the water table varied from ground surface or just below it along the western portion of the Gunnar Main Tailings to about 4 m below ground surface in the recharge area. Water levels in the Gunnar Central Tailings, although data are limited, indicated upward gradients in the central portion of the site. Depth to water is about 1.0 m. There was a slight decline in water levels during the summer months. Water levels in the Langley Bay Tailings indicated an upward gradient in the central portion of the site and downward at either end of the tailings. This downward gradient may be the result of increasing lake levels "recharging" the lower elevation areas of the tailings as the lake levels rise.

Hydraulic conductivity testing showed a general range of hydraulic conductivities from 1E-03 cm/sec to 1E-06 cm/sec. The shallow coarse fraction of the tailings had the highest hydraulic conductivity while at depth in the sandy tailings, the hydraulic conductivity was on the order of 2E-04 cm/sec. In the fine fraction of tailings, such as the topographic low on Gunnar Main and the tailings in Langley Bay, hydraulic conductivities were on the order of 1E-06 cm/sec. The field values are identical to the range of laboratory values measured for various textures of tailings.

The physical flow system in the tailings transports meteoric waters from recharge to discharge areas and dissolves a series of major cation salts along with trace elements and radionuclides. These elements then precipitate principally in discharge areas with evaporative concentration. The precipitation of iron in discharge areas causes the pH to drop which causes a preferential rise in porewater concentrations of magnesium along with other elements which are relatively insoluble under neutral to basic conditions. A series of these processes occurs across the tailings area as water seeps into the tailings in some areas and discharges in others.

The levels of Ra-226 within the porewaters of Gunnar Main typically showed values of 1-3 Bq/l with some values as high as 7 Bq/1. Specific activity levels of other radionuclides in solution were typically lower than those of radium. Uranium values in the main tailings porewater were typically 1-3 mg/l with some areas (N1C) being as high as 8 mg/l. In the discharge areas, the uranium values were lower (0.1-0.3 mg/l). Thorium-230 values were the lowest of all of the U-238 decay series radionuclides, reflecting the low solubility of thoriums in neutral and basic waters. The natural thorium isotopes showed an activity abundance of less than 10 percent of uranium series in the tailings solids and were at levels below the detection limit in the tailings porewater.

THE GUNNAR FIELD STUDY

The Gunnar Field Study consists of 10 volumes, each published separately. Volumes 2 to 10 are supplements to Volume 1, written as Appendices 1 to 9.

The 10 volumes are:

- Volume 1 - Summary Report
- Volume 2 - Test Procedures and QA/QC Program (Appendix 1)
- Volume 3 - Atmospheric Studies (Appendix 2)
- Volume 4 - Tailings Solids and Surrounding Soils (Appendix 3)
- Volume 5 - Groundwater (Appendix 4)
- Volume 6 - Surface Water (Appendix 5)
- Volume 7 - Biology (Appendix 6)
- Volume 8 - Waste Rock (Appendix 7)
- Volume 9 - Human Exposure Conditions (Appendix 8)
- Volume 10 - Permafrost (Appendix 9)

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5.0 INTRODUCTION

The Gunnar groundwater characterization study concentrated on groundwater sampling, field and laboratory chemical analyses of these samples, static water level measurements and field response tests. All the monitor wells (piezometers) were on the Gunnar Main, Gunnar Central, Langley Bay Tailings piles, and along the periphery of the waste rock pile. Wells were not installed in the Precambrian bedrock underlying the tailings or in the areas adjacent to the piles because of other higher priorities. The locations and depths of wells were chosen to allow an assessment of lateral and vertical hydraulic and chemical gradients, groundwater velocities and recharge/discharge conditions.

Major field campaigns were conducted during November 1984, March 1985, June 1985 and August 1985. During the first 2 campaigns, well points were installed from just below the water table to just above the bedrock surface (see Photograph No. 5.1). During all 4 field campaigns, water samples were collected, static water levels were measured and response tests were conducted. Additional static water level measurements were taken and response tests conducted to determine the site variation from January through May of 1985. The accessibility of wells and the time and equipment available for the field work were limited by weather conditions, primarily freezing and flooding, and physical access (i.e. no roads to get to the site or move on the site). The late contract award in October 1984 dictated the number and type of installations which could be installed.

This appendix presents a summary of data pertaining to the hydrogeology and geochemistry of the Gunnar Uranium Tailings. Details of the Tailings Solids and Surrounding Soils are presented in Volume 4, Appendix 3 and the Waste Rock Pile in Volume 8, Appendix 7. This appendix includes summaries of all hydrogeological and geochemical work performed to date on site, field and laboratory procedures, all data collected to date, and a general discussion of the results. A detailed interpretation of the results was not part of the terms of reference, however, the data were examined to ensure reasonableness.

PHOTOGRAPH NO. 5.1
Installing a monitor well.
November 1984

5.1 HISTORICAL DATA

The Gunnar minesite is located about 25 km southwest of Uranium City in Northwestern Saskatchewan, at the southern tip of the Crackingstone Peninsula on the north shore of Lake Athabasca. The mine/mill operation was operated from 1955 to 1964. During that period, it is estimated that 4.4 million tonnes of tailings were stored on surface with additional tailings placed underground during the later years of the operation. Figure No. 5.1 illustrates the key components of the mine mill complex.

The mine was first operated as an open pit and later as a conventional shaft and pillar operation. The ore was ground to 50 percent passing the 0.074 mm sieve (No. 200), processed and piped in a slurry to the Mudford Lake basin (Gunnar Main Tailings on Figure No. 4.1). Included with the tailings slurry was the ion exchange barren. The chemicals used in the processing were sulphuric acid, sodium chlorate and sodium chloride. The tailings slurry was discharged at about 30 percent solids without neutralization. Also included in the discharge to the tailings, was the sewage waste from the townsite. When the Gunnar Main Tailings area was filled, a notch was blasted in the rock outcrop at the north end, allowing the tailings to flow into a second depression known as Gunnar Central. When this depression filled, the tailings overflowed into Langley Bay on Lake Athabasca, forming a third tailings body known as Langley Bay Tailings.

Although several field studies have been conducted previously at, and around the Gunnar site, this study is the first to collect groundwater data from the Gunnar tailings. The lithology, structure and mineralization of the original ore body was first reported by Jollife, 1955. The results of a study on the water quality in the flooded, open pit is reported by Tones, 1982. The surface water and sediment quality of Langley Bay was reported by Ruggles et al 1978. The physical and chemical characteristics of the Gunnar tailings with emphasis on the impact to vegetation was reported by Kalin, 1981 and 1982. Other studies on the vegetation at and around the Gunnar tailings include Harms and Herbarium, 1982 and Murray and Horn-Johnson, 1982. The meteorology of the Gunnar site was investigated by Whiting et al 1982. Several publications have reported the results of studies on the geology, stratigraphy, surface water and groundwater conditions at the Lorado mill site which is approximately 20 km from the Gunnar site. These documents include Kermeen, 1981, Christiansen, 1982, and Whiting et al, 1982.

5.2 SAMPLING PLAN

5.2.1 Location, Depth and Frequency of Sampling

Figures Nos. 5.2 and 5.3 show the locations of all monitor wells (also called well points or piezometers) used for collecting groundwater samples, water level measurements and response (slug) testing for the tailings. Sample points for the waste rock pile are located and discussed in Volume 8, Appendix 7. Table 5.1 lists the monitor well identifications, northings, eastings, ground surface elevations, elevations of top of the well pipe, completion (screened) depths and the total depths of the holes. In addition to monitor wells; holes for thermistors, boreholes without wells, and some surface sample locations are included in Table 5.1. The identifications are coded as follows:

- GM: Gunnar Main Pile
- GC: Gunnar Central Pile
- LB: Langley Bay
- WR: Waste Rock Pile
- N: Nest of Installations

Each identification begins with 1 of the 5 codes listed above followed by a number. In many cases, the number is followed by a letter to uniquely identify each installation that is in a nest or a cluster.

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SITE PLAN

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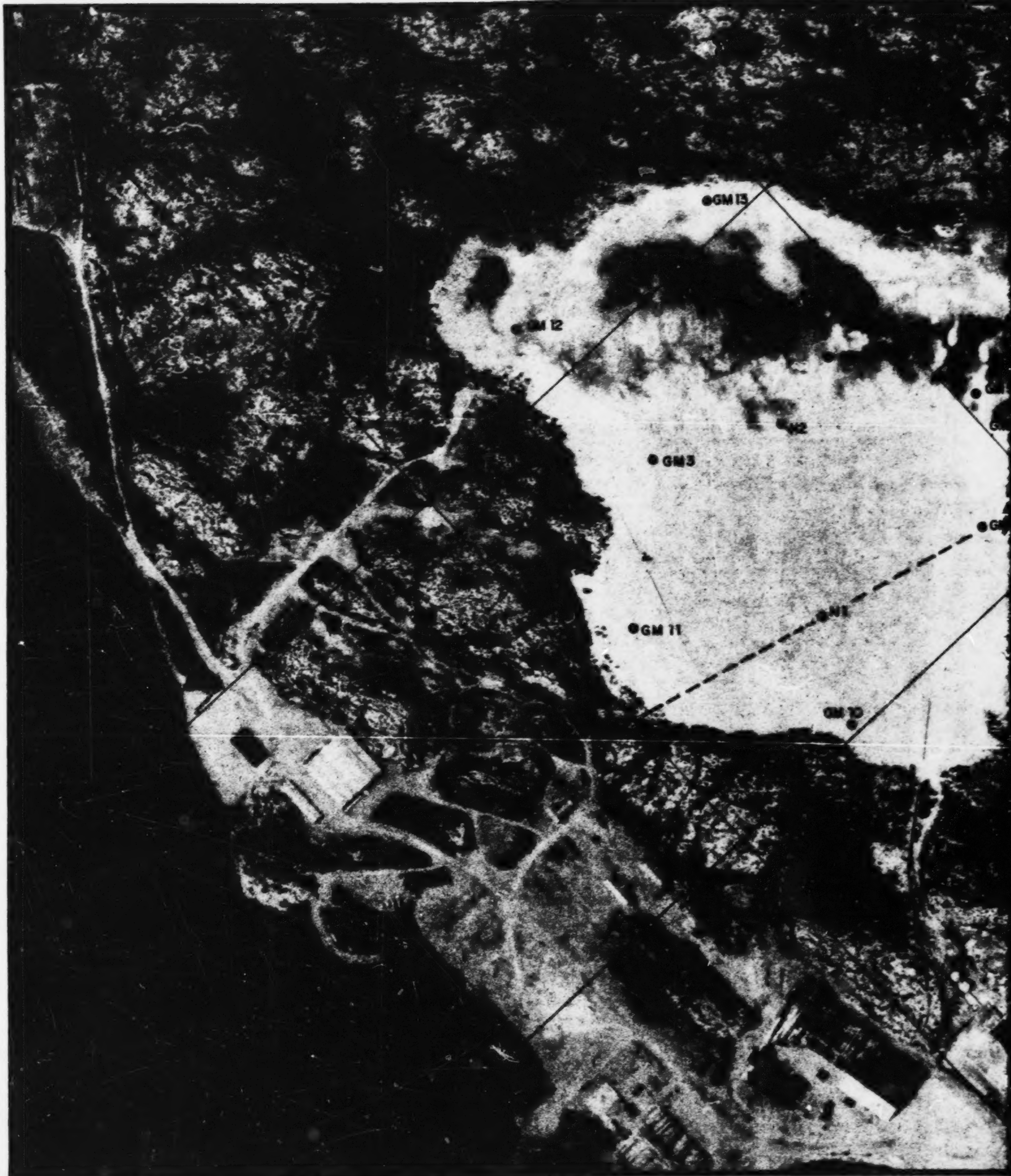
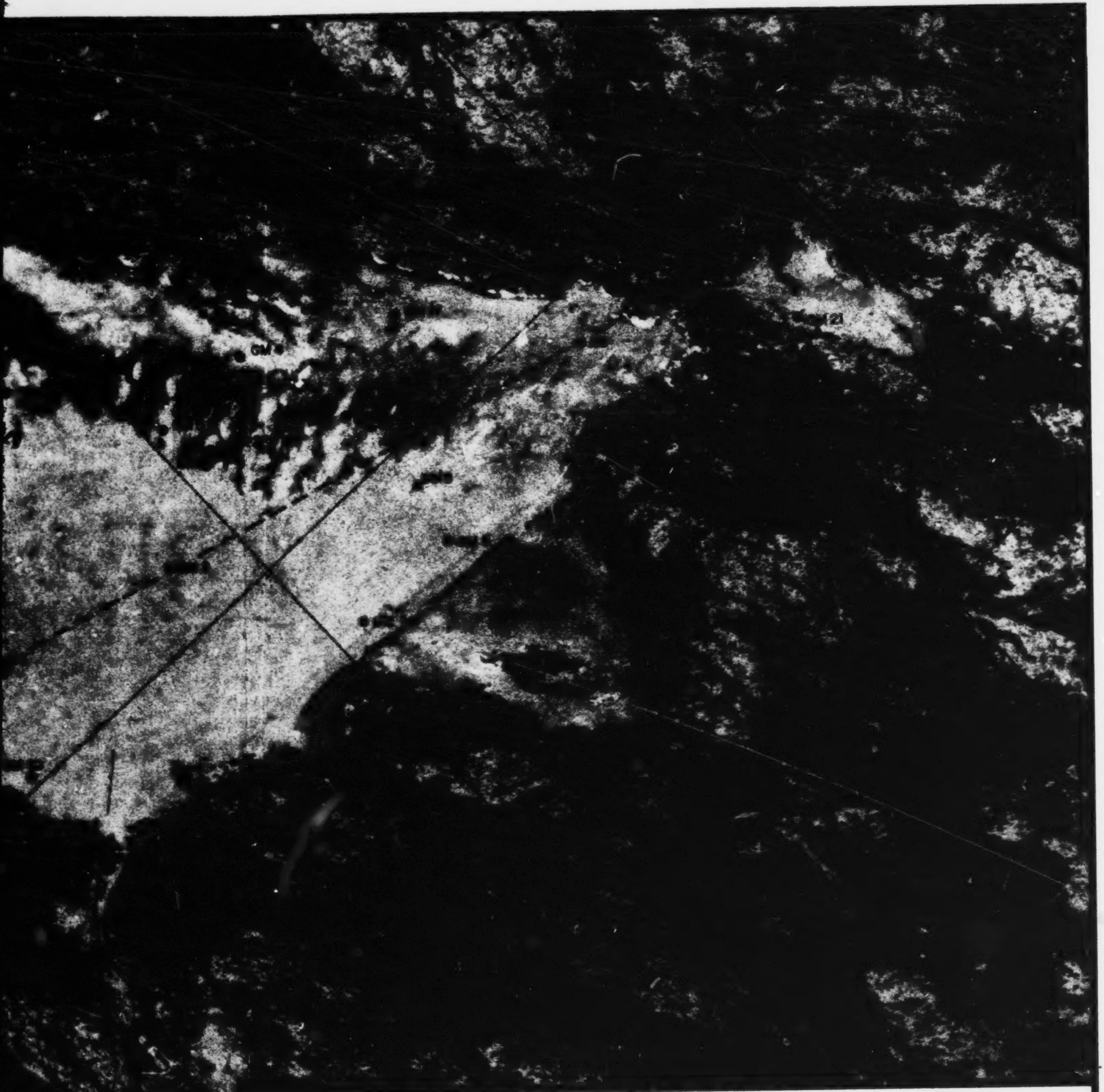
SCALE 1:20 000	DRAWN BY W. T.	FIGURE 5.1
DATE DEC. '85	APPROVED BY	


GM 13
GM 12
H2
GM3
GM 11
H1
GM 10



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SCALE 1:5000	DRAWN BY W.T.	FIGURE 5.2
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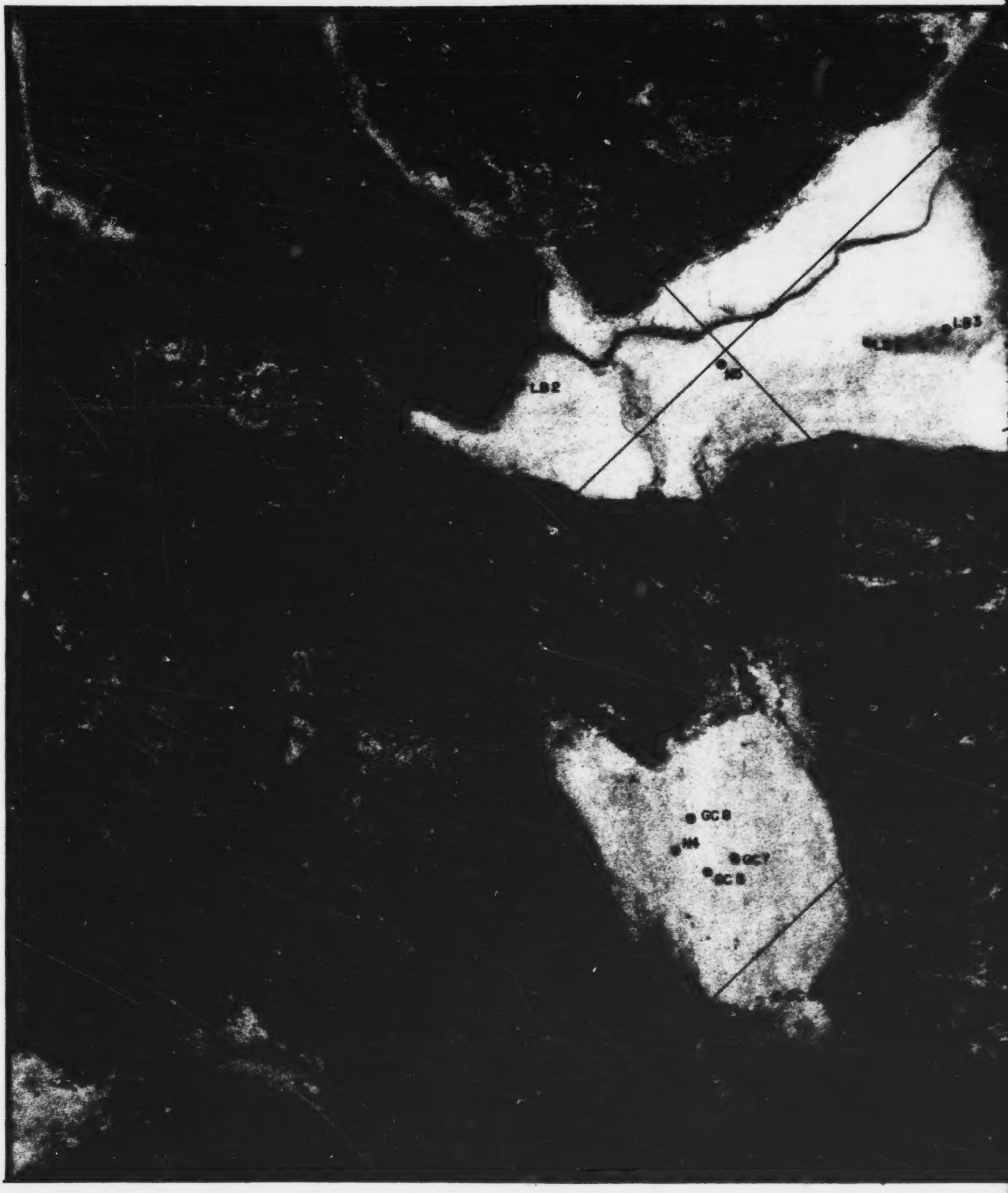
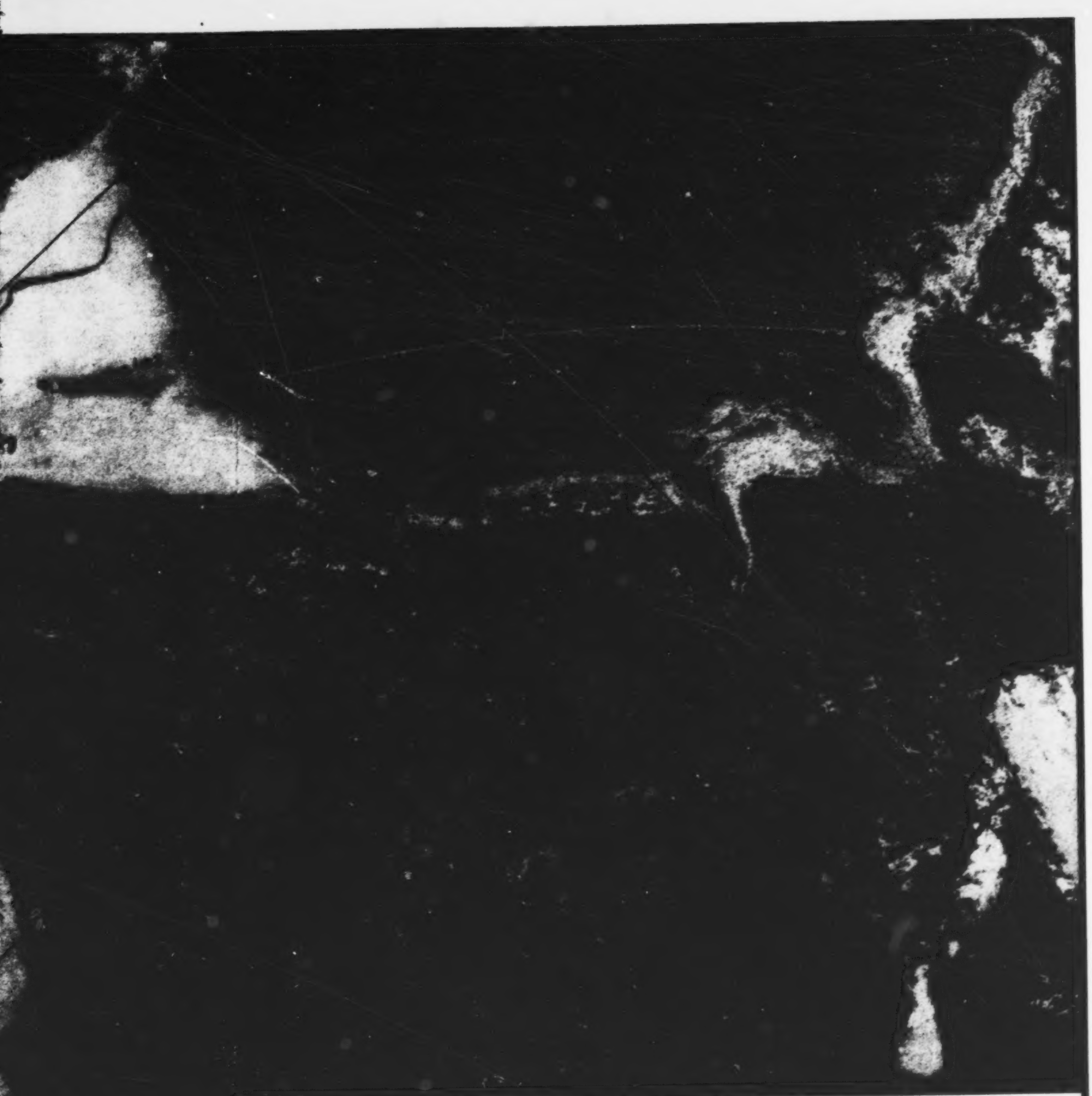

LB3
LB
LB2
N5
GC 8
N4
GC7
GC 6



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Gunnar Central + Langley Bay Tailings

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SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1:5000	DRAWN BY W.T.	FIGURE 5.3
DATE DEC. '85	APPROVED BY	

TABLE 5.1

TEST HOLE AND WELL INFORMATION

Location Identification	Northing (m)	Easting (m)	Relative Elev. (m) Ground	Relative Elev. (m) Casing	Top of Pipe Above Ground Surface (m)	Completion Depth Below Ground Surface (m)	Total Depth of Drilled Hole Below Ground Surface (m)
N1A	1230	3883	106.64	-	Hole Collapsed	Hole Collapsed	7.62
N1B	1231	3883	106.64	107.25**	0.56	3.70	6.10
N1C	1232	3883	106.50	106.88**	0.38(T)	9.67	11.89
N1D	1233	3883	106.29	106.89**	0.60	5.53	7.62
N1E	1227	3890	106.64	106.87	0.23	7.79	13.9
N1F	1227	3890	106.64	107.01	0.37(T)	4.15	4.9
N2A	1336	3702	101.83	102.07**	0.24	4.42	5.49
N2B	1336	3701	101.78	102.06**	0.28	5.72	5.49
N2C	1336	3701	101.79	101.94**	0.15	2.33	2.59
N2D	1336	3700	101.79	101.87**	0.08	1.63	1.83
N2E	1342	3700	101.81	102.17	0.36	7.60	19.6
N2F	1342	3701	101.81	102.29	0.48(T)	5.57	12.2
N2G	1342	3701	101.81	102.24	0.43	5.39	9.9
N2H	1342	3702	101.81	102.13	0.32	3.13	3.3
N2I	1342	3702	101.81	102.18	0.37	2.19	3.0
N2J	1342	3702	101.81	-	No Well	No Well	1.04
N3A	1900	4052	98.59	99.72/ 98.97**	1.13/ 0.38*	2.91	Installed by Vibration
N3B	1900	4052	98.62	99.85/ 98.98**	1.23/ 0.36*	2.81	Installed by Vibration
N3C	1900	4053	98.63	99.60/ 99.04**	0.97/ 0.41*	2.3±	Installed by Vibration
N3D	1899	4053	98.64	99.67/ 99.04**	1.03/ 0.40*	1.01	Installed by Vibration
N3E	1899	4056	98.77	99.03**	0.26	13.35	19.17
N3F	1899	4055	98.78	99.03**	0.25	7.98	8.38
N3G	1898	4054	98.74	99.02**	0.28	2.58	3.96
N4A	2585	4361	83.21	83.59**	0.38	5.41	5.79
N4B	2584	4361	83.08	83.50**	0.42	3.87	4.27
N4C	2585	4362	83.15	83.51**	0.36	2.33	1.98
N4D	2586	4362	83.22	83.98**	0.76	1.28	1.07
N5A	2990	4009	70.78	71.16**	0.38	11.67	16.31
N5B	2990	4009	70.75	71.17**	0.42	3.36	3.35
N5C	2990	4010	70.75	71.12**	0.37	2.10	2.13
N6A	1634	3905	99.87	100.37**	0.50(T)	11.00	11.25
N6B	1634	3905	99.90	100.38**	0.48	5.15	5.20
N6C	1634	3905	99.90	100.23**	0.33	3.93	4.0
N6D	1635	3904	99.89	100.42**	0.53	2.97	3.0
N6E	1635	3903	99.88	100.31**	0.43	1.95	2.0

TABLE 5.1 (continued)

Location Identification	Northing (m)	Easting (m)	Relative Elev. (m) Ground	Relative Elev. (m) Casing	Top of Pipe Above Ground Surface (m)	Completion Depth Below Ground Surface (m)	Total Depth of Drilled Hole Below Ground Surface (m)
GM1A	1537	4107	104.35	-	No Well	No Well	No Drilling
GM2A	1426	3928	104.10	-	Thermistors Inst.(T)	5.27	8.4
GM2B	1427	3928	104.10	104.55	0.45	6.97	7.0
GM2C	1425	3928	104.10	104.45	0.35	3.82	3.85
GM2D	1425	3928	104.10	-	No Well	No Well	1.3
GM3A	1214	3631	101.98	-	Thermistors Inst.(T)	4.40	19.8
GM3B	1214	3631	101.98	102.36	0.38	9.90	Installed by Vibration
GM3C	1215	3632	101.98	102.50	0.52	4.14	4.6
GM3D	1215	3632	101.98	102.58	0.60	4.28	4.6
GM3E	1216	3633	101.98	102.48	0.50	4.36	4.6
GM4A	1632	3815	100.92	-	Thermistors Inst.(T)	4.20	4.8
GM4B	1631	3815	100.98	101.38**	0.40	4.67	4.6
GM4C	1632	3815	100.92	-	No Well	No Well	1.22
GM5A	1519	3819	101.46	-	No Well	No Well	No Drilling
GM6A	1543	3863	101.68	101.98	0.30(T)	4.15	11.0
GM6B	1542	3863	101.68	102.10	0.42	2.80	2.8
GM6C	1543	3863	101.68	-	No Well	No Well	1.37
GM7A	1370	3616	99.94	100.61**	0.67	2.0±	Installed By Vibration
GM8A	1673	4034	101.36	-	No Well	No Well	No Drilling
GM9A	1658	4107	101.44	-	No Well	No Well	4.65
GM9B	1658	4107	101.44	101.81	0.37(T)	4.10	4.10
GM9C	1657	4107	101.41	101.71**	0.30	3.54	3.6
GM10A	1171	3988	109.69	-	No Well	No Well	No Drilling
GM11A	1071	3751	104.10	-	No Well	No Well	No Drilling
GM12A	1197	3428	100.95	101.22	0.27	3.00	3.6
GM12B	1197	3428	100.95	101.35	0.40	1.77	1.8
GM13A	1444	3466	100.60	100.92	0.32	6.86	9.8
GM13B	1444	3467	100.60	100.98	0.38	3.12	3.2
GM17A	1781	3893	99.71	-	No Well	No Well	7.15
GM17B	1781	3894	99.68	100.02**	0.34	3.30	3.4
GM17C	1780	3894	99.60	99.95**	0.35	1.80	1.8
GM18A	1430	3678	100.34	_	No Well	No Well	No Drilling

TABLE 5.1 (continued)

Location Identification	Northing (m)	Easting (m)	Relative Elev. (m) Ground	Relative Elev. (m) Casing	Top of Pipe Above Ground Surface (m)	Completion Depth Below Ground Surface (m)	Total Depth of Drilled Hole Below Ground Surface (m)
GM19A	1563	3667	101.24	-	No Well	No Well	3.9
GM19B	1563	3667	101.00	101.65**	0.65	3.70	3.7
GM19C	1563	3668	101.41	101.99**	0.58	2.47	2.5
GM20	1550	3870	100.0±	-	Test Pit	No Well	1.43
GM21	2082	4185	99.9±	-	0.1	0.90	1.00
GM22	1270	4136	104.5±	-	0.2	0.80	0.90
GM23	1646	4200	99.5±	-	0.1	0.90	1.00
GM24	1648	4366	98.5±	-	0.1	0.90	1.10
GM25	1670	3938	99.2±	-	No Well	No Well	No Drilling
GC5A	2596	4400	83.11	-	No Well	No Well	9.8
GC5B	2597	4400	83.11	83.35	0.24	3.10	4.0
GC5C	2597	4400	83.11	83.43	0.32	3.81	4.4
GC6	2560	4546	82.9±	-	No Well	0.02	No Drilling
GC7	2630	4405	82.1±	-	No Well	0.01	No Drilling
GC8	2628	4340	82.2±	-	No Well	0.01	No Drilling
LB2A	2813	3877	69.89	-	No Well	No Well	19.8
LB2B	2813	3877	69.89	70.24	0.35	3.59	3.6
LB2C	2813	3878	69.89	70.29	0.40	3.38	4.2
LB3A	3192	4154	69.84	70.22	0.38	1.40	1.4
LB3B	3192	4154	69.84	-	No Well	No Well	13.1
LB3C	3191	4154	69.84	70.24	0.40	3.60	3.7
LB7A	3119	4105	69.89	-	No Well	No Well	11.3
LB7B	3119	4105	69.89	70.24	0.35	4.10	4.2
LB7C	3119	4106	69.89	70.22	0.33	2.13	2.2
WR1	465	4555	69.0±	-	0.1	0.90	1.00
WR2	465	4727	72.8±	-	0.1	0.90	1.00
WR3	622	4790	72.5±	-	0.1	0.90	1.00
WR4	718	4750	73.8±	-	0.3	0.80	0.90
WR5	750	5030	72.0±	-	0.1	1.00	1.10

* Cut Back From Original Length on 03/08/85.

** Elevations Surveyed. Remaining Elevations Were Calculated By Adding the Pipe to the Ground Elevation.

± Elevations were estimated from the contour plans.

(T) - Thermistor String Installed.

The elevations referenced in Table 5.1 were determined from on-site benchmarks which were established as follows:

TBM 0 - Top of turn buckle on a large steel roller drum by the airstrip, assumed elevation 100 m.

TBM 14 - Northeast corner of main shaft building top of steel rail on top of concrete foundation, elevation 75.641 m.

The water sampling frequency was quarterly. Some wells were sampled up to 3 times, others less often. Generally, sampling during the March campaign was restricted due to the fact that many of the piezometers were frozen. Where possible, water levels were measured during each of the 4 major field trips. In addition, water levels were measured approximately at a biweekly interval from January through May 1985. Response tests were performed twice on most wells, once when first installed and again, if possible, during the June 1985 campaign. Some wells were not tested in June, due to frozen water or flooded locations. In permafrost areas, as described in Volume 10, Appendix 9, some frozen piezometers were found in the August campaign as well.

5.2.2 Rationale for Locations, Depth, Tests and Parameters

Considerations in planning the groundwater study were:

- The need for adequate hydrogeochemical characterization including measurement of groundwater quality, lateral and vertical chemical and hydraulic gradients, and the determination of recharge and discharge conditions. Perform tests which would allow calculation of values of hydraulic conductivity.

- Coordination of the groundwater study with other phases of the program, particularly tailings solids, permafrost and surface water.
- Schedule, budget and logistical constraints.

Based on the considerations listed above, the following approach was taken:

- Limit drill hole diameters to 56 mm and use 35 mm diameter well points for all test holes and monitor wells. This allowed use of a portable rig for all drilling and permitted installation of more wells. The test holes and monitor wells were used to collect water samples, measure water levels, perform response tests, collect tailings and soil samples for geotechnical and geochemical analyses, geologic logging and determination of depths and thicknesses of permafrost. A pump test could not be performed in the small diameter well points. It was decided that response tests would supply sufficient time versus recovery data for the calculation of insitu values of hydraulic conductivity.

- Areas adjacent to the tailings and bedrock beneath the tailings were not drilled. The study was limited to the tailings piles, the underlying clay and zones of seepage around the tailings and waste rock area. Bedrock outcrops are prevalent around the Gunnar site and where present, overburden soil is generally thin. Geological studies and the history of the mine indicated that the bedrock beneath and surrounding the site is very tight and an unlikely pathway for seepage migration. The Gunnar pit lies within 10 m of St. Mary's Channel on Lake Athabasca and is within a fractured, bedrock zone. The pit is approximately 100 m deep and according to Jack Botsford, Ex-Mine Manager, the mining operation never suffered a seepage problem due to groundwater inflow from the lake to the pit (Botsford, 1984). The bedrock appears to have a low gross permeability with bedrock groundwater flow likely occurring in fractures. Drilling into the bedrock would have been expensive and difficult with uncertain results (i.e. uncertainty of intersecting representative fractures), and it was subsequently decided not to drill into the rock beneath the tailings or in off tailings pile areas.

- The emphasis of the drilling and sampling effort was on the Gunnar Main Tailings area. The Gunnar Main Tailings area is much larger and thicker than the other 2 areas. Therefore, it was expected that the largest variation in groundwater quality, tailings geotechnical, geochemical, hydraulic properties, and permafrost conditions would be found on this pile. An adequate data set was developed for the other areas as well.

- Rather than single well points, the use of nests of well points was emphasized. Nests allowed collection of data used to determine vertical chemical and hydraulic gradients and recharge and discharge conditions. The nests were located in topographically low areas (i.e. areas of expected groundwater discharge), and in topographically high areas (i.e. areas of expected groundwater recharge). Single well points were distributed spatially to adequately define the water table configuration and to ensure representative groundwater quality data from all tailings areas.

5.2.3 Special Analyses

Specialized analyses performed for the groundwater phase of the Gunnar mill site characterization program included tritium analyses on samples collected from wells in Nest No. 6. Tritium can be an excellent environmental tracer of relatively young groundwater because it was at low activities throughout the earth's atmosphere prior to the advent of above ground testing of nuclear weapons in the early 1950's. Therefore, groundwater with low tritium activity is probably older than 35 years (i.e. left the atmosphere more than 35 years ago). Samples from wells in Nest No. 6 and water from St. Mary's Channel were analyzed for tritium. These analyses were intended to give an estimate of the travel time for groundwater moving vertically through the tailings at the location of Nest No. 6.

5.3 MATERIALS AND PROCEDURES

5.3.1 Installation of Monitor Wells

Monitor wells installed at the Gunnar site were modified Casagrande drive-point piezometers designed by Blair et al 1980 for studies at the Nordic Uranium Tailings in Elliot Lake, Ontario (Figure 5.4). They were constructed entirely of plastic material to avoid corrosion in acidic water. A porous polyethylene cartridge (Vyon) with a 50 micron pore size was used for the piezometer screen. The porous cartridge was found necessary to prevent silt size particles from entering the piezometer pipe. The porous cartridge formed a sleeve over a 150 mm by 30 mm schedule 80 PVC perforated barrel. The porous cartridge was placed between the drive point tip and a female couplings, and sealed with a silicone compound. The final screen length was 127 mm.

The majority of the monitor wells were installed during 2 phases of work commencing in November 1984 and March 1985, which were to be coordinated with other aspects of the field program due to the logistical concerns as a result of site accessibility and climatic conditions. Installation was coordinated with the solids sampling field work when a portable skid mounted vibratory rotating drill was on site. One partial nest of wells was installed by hand using a gasoline powered percussion drill. The majority of the monitor wells were installed during the winter when frost conditions prevented the use of hand installation techniques. A limited number of wells were installed with a hand auger in June 1985.

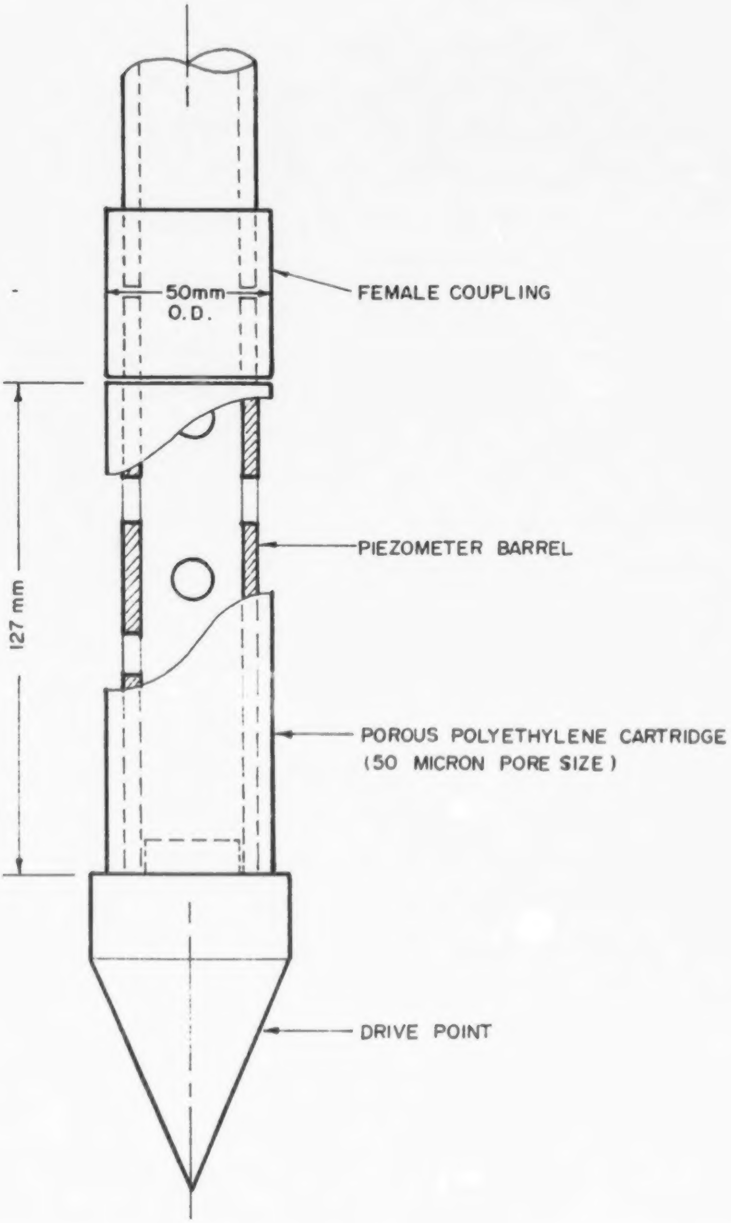
Monitor wells were installed in individual bore holes approximately 56 mm in diameter. Piezometer screens were 50 mm in diameter. The riser pipes (blank casing) were made of 2.0 m length, 35 mm inside diameter, schedule 40 PVC sections. These sections were joined to the well points and to each other with PVC bonding cement. The last section of each well was cut off close to land surface and capped with a tension PVC cap. Because of the date of contract award, a hollow stem auger rig could not be used for drilling and piezometers had to be installed in the bore hole after small diameter casing, used in drilling and soil sampling, was removed from the bore hole. In some cases, the hole collapsed and wells could not be installed at depth. No seals were used above the monitor well because the tailings collapsed quickly in the borehole below the water table and packed around the piezometer intake and piezometer pipe. In some instances, piezometer tips were vibrated down into sloughed material in the bottom of a borehole.

Monitor well locations were concentrated on the Gunnar Main Tailings (Figure No. 5.2). The areal extent and thickness of the tailings was much greater at Gunnar Main than the other 2 tailings areas (Figure No. 5.3). Because of the variation in elevation (hence depth to water) and grain size distribution (the discharge spigots were located at Gunnar Main), it was felt that the largest variation in porewater movement, hydraulic conductivity and geochemistry would be found in this area.

Monitor well locations were divided into 2 categories; large multiple piezometer nests and single or double piezometer nests. Four multiple piezometer nests were located on Gunnar Main and 1 nest was located on each of Gunnar Central and the Langley Bay Tailings areas. The multiple nests on Gunnar Main were located in areas of expected recharge to tailings porewater (i.e. topographically high areas, e.g. N1) and expected discharge areas (i.e. topographically low areas, e.g. N2, N3, N6). The topographic highs are in areas near discharge spigots and would likely have coarser-fraction tailings and a greater depth to the water table than the topographic low areas. It was anticipated that these nests would give a representative cross-section of the hydraulic and geochemical conditions within and below the tailings.

5.3.2 Water Level Measurements

Upon installation of piezometers, water levels were monitored during each major field campaign and approximately biweekly through the winter of 1985. Because of the logistics of site visits, routine water level measurements were difficult to obtain.


50mm
O.D.
FEMALE COUPLING
PIEZOMETER BARREL
127 mm
POROUS POLYETHYLENE CARTRIDGE
(50 MICRON PORE SIZE)
DRIVE POINT

DESIGN OF PIEZOMETER TIPS USED IN TAILINGS (BLAIR ET AL, 1980)

BBT Geotechnical Consultants Ltd. BBT GEOTECHNICAL CONSULTANTS LTD.	NATIONAL URANIUM TAILINGS PROGRAM **GUNNAR FIELD STUDY** SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE	DATE	DRAWN BY	
N.T.S.	DEC. '85	W.T.	FIGURE 5.4

Water level measurements were taken using 3 water level sounding devices:

1) A water level sounder using a probe and incremental electrical cable. This device was difficult to use in extremely cold weather as the cable was too brittle to wind and unwind.

2) A second electric water level tape which had a probe connected to 2 thin insulated wires which in turn were connected to an ohmmeter.

3) The third sounding device consisted of a metal weight attached to the end of a cloth measuring tape.

The primary device used was the electrical sounder tape (1) with the cloth tape (3) being used in very cold weather. All the water levels were measured as the depth below the top of the uncapped monitor well pipe.

Water levels were monitored, as piezometers were installed, between December 1984 and August 1985. All water level measurements taken to date are included in this appendix. During the winter months many piezometers had water levels which represented frozen conditions. Results indicate that where water levels are on the order of 1.5 m below ground surface or less many piezometers had ice in them during the winter months. Some water levels are recorded as being dry in the water level data, however, they may have been frozen and the water level sounder obviously did not obtain a reading.

Some piezometers encountered frozen conditions at depth and in the summer months. This is the result of ice lenses present in the tailings causing the water to freeze in the piezometer pipe adjacent to the lenses. Caution should be taken when interpreting water levels in these piezometers. Data should be correlated with permafrost information in Volume 10, Appendix 9. Correlation with this data should also be made when interpreting tailings porewater flow direction, as the ice lenses may result in confining conditions or highly irregular vertical gradients.

Piezometers located in the Langley Bay tailings were submerged during the summer months as water levels in Lake Athabasca rose about 1.5 m or about 1 m above ground surface at some locations.

5.3.3 Hydraulic Conductivity Determinations

Hydraulic conductivity tests were performed by carrying out response tests (slug tests) on monitor wells utilizing Hvorslev's rising head method as described below. Response tests were performed either when the wells were initially installed or when piezometers were flushed out prior to geochemical sampling, to optimize time in the field.

Response tests were conducted by removing the water column in the well and monitoring the rate of water level recovery. These tests give a measure of hydraulic conductivity in the immediate vicinity of the piezometer tip. By testing a number of piezometers within and below the tailings, the spatial variability in hydraulic conductivity can be estimated and representative values for tailings of various textural types can be determined.

The procedure used for the response tests was as follows:

i) Measure and record the water level at the well.

ii) Pump or bail the well until dry.
Note: Some wells recovered too quickly to purge completely.

iii) At planned times, note water levels since purging the well until well recovers to, or close to, the original water level or until a sufficient data set has been acquired.
Note: The time intervals for water level measurements are based on the speed of water level recovery.

5.3.4 Water Sampling

Water samples were collected during 4 campaigns, December 1984, March 1985, June 1985 and August 1985. Two sets of samples were collected for most monitor wells, while some had 3 sets collected.

Water samples were generally collected from the wells using a varistaltic pump. Due to low yields and overnight freezing during the 2 winter campaigns, usually all extracted water was used as the sample. The pump, filter apparatus, nitric acid, pH paper, specific conductance meter and alkalinity kit were all used within a portable wooden and fiberglass insulated hut. The hut was heated with a kerosene heater and positioned over the well head with the helicopter so samples would not freeze in the plastic tubing from the well to the varistaltic pump.

Table 5.2 lists the type and the supplier of most of the equipment. The field parameters were measured in a flow-through bath prior to sample filtration. These field analyses are described in the next subsection. All samples collected for laboratory analyses were filtered through a 0.45 micron filter. Samples collected for analysis of anions or tritium were not acidified. Samples collected for analysis of cations and radionuclides were acidified with reagent grade nitric acid to a pH of less than 2.0. The pH of the acidified samples was checked with pH paper. If the pH was not less than 2.0, more acid was added. The volume of each sample and the volume of acid added are recorded on the field forms entitled Groundwater Sampling Records. The pump and all equipment were rinsed with tap water from Uranium City between samples during the winter campaigns.

TABLE 5.2

SAMPLING/FIELD ANALYSIS EQUIPMENT

Equipment Name	Type	Supplier
Filter Holder	Backwash	Geotech Environmental Equipment
Filter	142 mm Diameter 0.45 Micron Openings	Geotech Environmental Equipment
Alkalinity Kit	Titration Gun	Prairie Industrial Chemicals
Kim Wipes	Disposal Wipes	Prairie Industrial Chemicals
Conductivity Meters	YSI Portable	Fisher Scientific Ltd.
Salinity-Conductivity Temperature Probe	For YSI Meter	Fisher Scientific Ltd.
pH/Temperature Meter	Fisher (#13-637-7)	Fisher Scientific Ltd.
Nitric Acid	500 ml Bottles	Fisher Scientific Ltd.
Acid Dispensette	1.0 to 5.0 ml	Fisher Scientific Ltd.
Buffer Solutions	pH = 2.0, 4.0, 7.0 and 10.0	Fisher Scientific Ltd.
Pocket Thermometer	-15 to 105°C	Fisher Scientific Ltd.
pH Paper	0.0 to 3.0	Fisher Scientific Ltd.
Varistaltic Pump	#13-875-109	Fisher Scientific Ltd.
Flow-Through Bath	Teflon Container	CanLab
Bailer	Stainless Steel	Bask Inc.
*Water Level Indicator	Sounder	Hoskin Scientific Ltd.
Sample Bottles	Plastic	SRC Laboratory

Note: This list is not complete, but contains most of the predominantly used equipment.

During the June and August 1985 campaigns, all samples were collected with a stainless steel bailer. The bailer was approximately 800 mm long with an inside diameter of approximately 20 mm. When practical, wells were purged with the bailer 1 or 2 days prior to sample collection. The samples were put in 1 litre bottles and transported by backpack to a portable laboratory on the landed barge. Field parameters were measured and samples filtered and acidified, when appropriate, at the portable laboratory. The bailer and all equipment were rinsed with water collected from St. Mary's Channel between each well and each processed sample. All records of sampling procedures are included in this Appendix.

Prior to filtration, the samples were analyzed for the following field parameters: temperature, pH, specific conductance and alkalinity.

Temperature was measured by placing the end of a thermometer into the flow-through bath. Also, the temperature was checked with the temperature probe on the specific conductance (YSI) meter.

The pH was analyzed in the following way:

i) The temperature of the pH buffer solution was allowed to stabilize with the sample using the flow-through bath.

ii) The temperature dial on the pH meter was adjusted to the temperature of the sample.

iii) The pH meter was calibrated with the 2 pH buffer solutions that bracket the pH of the sample by placing the probe in 1 solution and adjusting with the calibration dial; then after cleaning, it was placed in the other solution and the slope dial adjusted. Finally, the probe was checked in the first solution to insure correct reading within ±0.02.

iv) The pH of the sample was measured and recorded.

v) The pH of the 2 bracketing buffer solutions was measured and recorded.

Specific conductance analyses were performed as follows:

i) The temperature was checked with the temperature probe.

ii) The meter was adjusted to the correct temperature with the temperature adjustment dial.

iii) Specific conductance was measured on the high range. Adjustments to lower ranges were made, as appropriate, until the needle read between 50 and 500 on the specific conductance scale.

iv) The specific conductance value was read and recorded.

Alkalinity measurements were taken as follows:

i) 100 mm of unfiltered sample was measured with a graduated cylinder.

ii) This sample was poured into a narrow necked flask.

iii) The pH meter was calibrated against pH 4.0 and 7.0 buffer solutions at the same temperature as the sample.

iv) The pH probe was inserted into the flask.

v) The titration gun was set to zero reading.

vi) Drops of sulfuric acid titrant were added to the flask from the gun while swirling the sample until the pH reading was 4.5.

vii) The alkalinity reading was recorded from the handle of the titrant gun.

viii) Sulfuric acid was added until the pH reading was 4.2 and again read, and this alkalinity reading was recorded.

Only samples for analyses for radionuclides and metals were preserved with nitric acid until a pH of less than 2.0 was obtained.

5.3.5 Quality Assurance/Quality Control

Quality assurance/quality control was provided for the field program by:

- Working in teams of at least 2 members for all well installations, sampling and testing.
- Following specific procedures as described in Subsection 5.3.4.
- Filling out standard field forms for all data collection activities.
- Collecting at least 1 replicate sample during each water sampling campaign. These replicate samples were split between 2 laboratories. BEAK performed the bulk of the stable chemistry analyses and SRC performed the stable chemistry on the replicates. SRC performed the bulk of the radionuclide analyses and Monenco performed the radiochemistry on the replicates.

In June and August 1985, samples were first sent to the on-site portable laboratory for measurement of field parameters, filterization and acidification (see Photograph Nos. 5.2 and 5.3). This delay of from several hours up to 1 day may have effected the chemistry of the sample. To allow the determination of these effects, a comparison was made of field parameters measured at the borehole compared to field parameters measured at the portable laboratory (see Table 5.3). Generally slightly higher pH and conductivity values were measured at the portable laboratory.

PHOTOGRAPH NO. 5.2

Groundwater sampling equipment.

PHOTOGRAPH NO. 5.3

Sampling the groundwater at Nest No. 1.
June 1985

TABLE 5.3

FIELD-LABORATORY CHEMISTRY COMPARISON

JUNE 25, 1985

Well	pH		Temperature (^oC)		Specific Conductance (umhos/cm)	
	Downhole	Portable Laboratory	Downhole	Portable Laboratory	Downhole	Portable Laboratory
N1E	7.26	7.03	5.8	15	1780	2490
N1C	6.22	6.46	5.8	12	3120	4130
N6E	5.96	6.07	6	16	2750	3520
N6D	5.78	5.74	3	15	3080	4520
N6C	5.81	5.95	3	14	3250	4650
N6B	6.08	6.24	2	15	2340	3340
GM3E	6.44	6.60	4	13	2300	3100
GM3D	6.48	6.57	2	14	2230	3100
GM3B	5.93	6.13	4	13	3500*	4150

* In bottle rather than downhole.

Although the field conditions, e.g. freezing wells and samples, low well yields and lack of transportation, caused difficulties in sampling and testing procedures, care was taken to avoid cross-contamination and to collect as representative a sample as possible. The field forms, including comments and notes, indicate where compromises were required in the data collection process. These forms will aid the reviewer and user of the data in determining their accuracy and validity. A description of laboratory procedures, analytical methods and quality assurance/quality control practices for the analysis of water samples is presented in Volume 2, Appendix 1.

All samples were carried by the field crew from the Gunnar site to Uranium City by helicopter or float plane from where they were transported by air to Saskatoon. Samples whose destination was Monenco were shipped by air courier from Saskatoon to Calgary. Samples for Saskatchewan Research Council (SRC) were delivered by BBT personnel. Samples for BEAK and the University of Waterloo were shipped to Toronto by air courier.

5.4 DETAILED RESULTS

The field and chemical groundwater data are presented in this section. Section 5.4.1 contains the water sampling records. Section 5.4.2 contains the static water level information. Section 5.4.3 contains the response test (slug test) data and Section 5.4.4 contains all the laboratory water quality results. Drilling records are included in Volume 4, Appendix 3.

5.4.1 Groundwater Sample Records

The following sheets present the field sampling records.

The depth of well recorded is the distance from the top of the pipe without the cap to the bottom of the screen.

The depth to the screen is the distance from the ground surface to the top of the screen.

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Main
LOCATION ID NIC
SAMPLE ID B1 to B6
STATIC WATER LEVEL (m) 5.88
SAMPLE DEPTH (m) 10.05
SAMPLING DATE 84/12/10
SAMPLING TIME:
Start 13:30
Finish 15:15

FINAL FIELD VALUES

	Surface	Down Hole
pH (S.U.)	6.88	
Ec (umhos/cm)	5500	
Eh (millivolts)		
TEMP. (°C)	4	
ALKALINITY (mg/l CaCO$_3$)	767 9 4.49	

LOCATION DESCRIPTION
Towards Top of Tailings Pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	–	Start Pumping

NUMBER OF CONTAINERS COLLECTED

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre		B5 & B6	2.0 ml HNO$_3$
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml	B2	B1	1.0 ml HNO$_3$
	1 liter		B4	2.5 ml HNO$_3$
	700 ml		B3	1.5 ml HNO$_3$

1.6 N Lot #4093

REMARKS
Used 5 Filters
200 ml was removed from B3 and labeled N1D-B1-841210

FIELD REP(S) Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 5.88
DEPTH OF WELL (h_1) (m) 10.18
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 9.67

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailing
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
Ec/pH/Eh METER ID's 301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION 13:40
pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	Moneco
DATE(S) SHIPPED	84/12/13	84/12/14	84/12/13
METHOD OF SHIPMENT	Purolator	Hand	Purolator
SAMPLE CLASSIFICATION	B1 & B2	B5 & B6	B3 & B4

NOTES
NIC 85/12/10

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Main
LOCATION ID N2A
SAMPLE ID B1 to B4
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 84/12/04
SAMPLING TIME
Start 12:15
Finish 13:45

FINAL FIELD VALUES

	Surface	Down Hole
pH (S.U.)	6.61	
Ec (umhos/cm)	4000	
Eh (millivolts)		
TEMP (°C)	4	
ALKALINITY (mg/l $CaCO_3$)	413 @ 4.35	

LOCATION DESCRIPTION ≈ 200 m from west edge of pile; ≈ 300 m from south side of pile: number from east to west A-D

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		B3	2.5 ml
	150 ml			
	50 ml			
SPECIFY OTHERS	100 ml	B1	B2	0.5 ml
	1 liter		B4	2.0 ml

REMARKS: Titrate 1.6 N Lot #4093
Used 1 Filter

FIELD REP(S) McKenzie

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m) 5.49
DEPTH OF WELL (h_1) (m) 4.79
WELL DIA (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 4.42

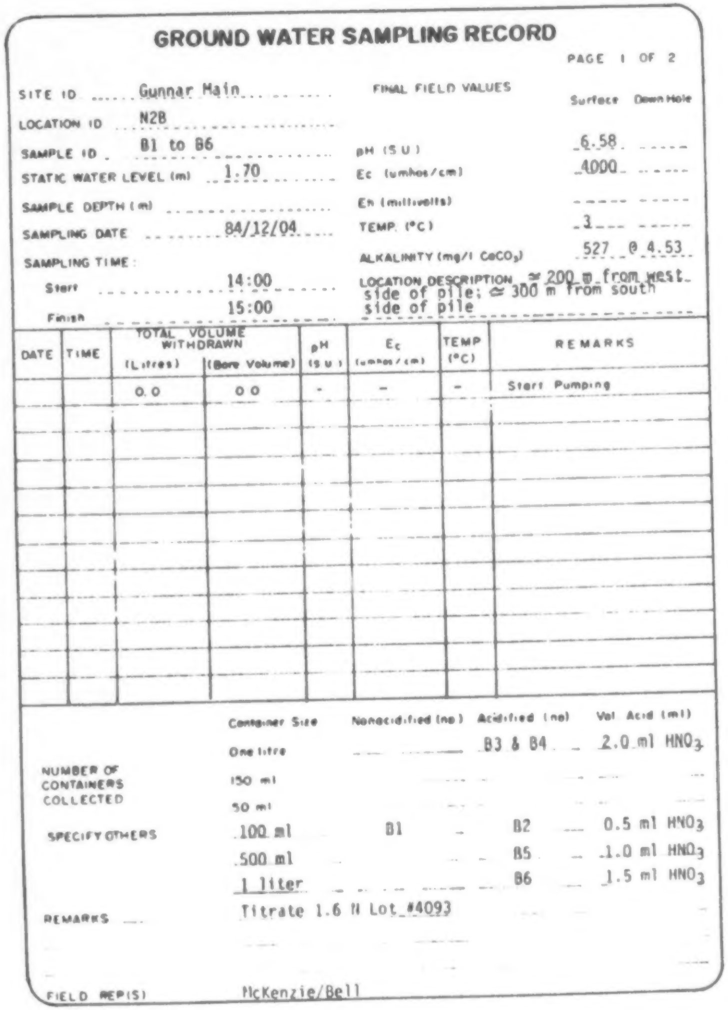
SAMPLING INFORMATION
WITHDRAWAL METHOD Peristaltic
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I D
Ec/pH/Eh METER ID's 301196

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION 12:28 7.0 3.99
pH AFTER MEASUREMENT 7.0 FOR STANDARD pH 7.0
pH AFTER MEASUREMENT 4.0 FOR STANDARD SOLUTION pH 4.0
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC
DATE(S) SHIPPED	84/12/13	84/12/14
METHOD OF SHIPMENT	Hand	Hand
SAMPLE CLASSIFICATION	B1 & B2	B3 & B4

NOTES N2A 84/12/04



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Main

LOCATION ID N2B

SAMPLE ID B1 to B6

STATIC WATER LEVEL (m) 1.70

SAMPLE DEPTH (m)

SAMPLING DATE 84/12/04

SAMPLING TIME:

Start 14:00

Finish 15:00

FINAL FIELD VALUES	Surface	Down Hole
pH (S U)	6.58	
Ec (umhos/cm)	4000	
Eh (millivolts)		
TEMP. (°C)	3	
ALKALINITY (mg/l $CaCO_3$)	527	@ 4.53

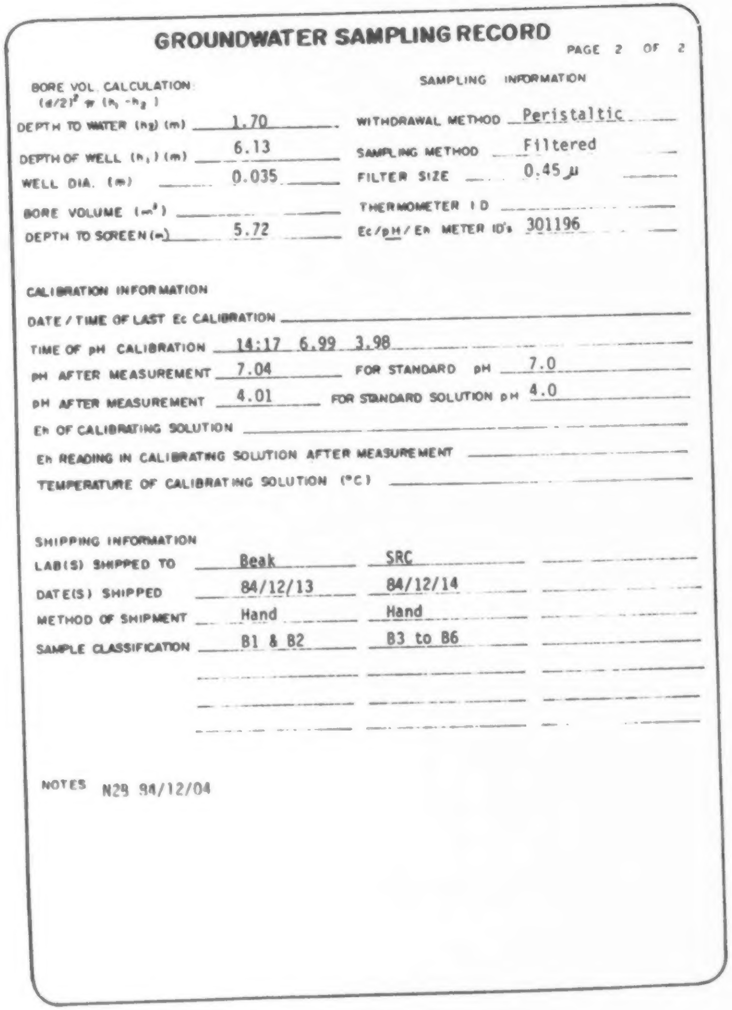
LOCATION DESCRIPTION ≃ 200 m from west side of pile; ≃ 300 m from south side of pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S U)	E_c (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
	One litre		B3 & B4	2.0 ml HNO_3
	150 ml			
	50 ml			
SPECIFY OTHERS	100 ml	B1	B2	0.5 ml HNO_3
	500 ml		B5	1.0 ml HNO_3
	1 liter		B6	1.5 ml HNO_3

REMARKS Titrate 1.6 N Lot #4093

FIELD REP(S) McKenzie/Bell



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 1.70

DEPTH OF WELL (h_1) (m) 6.13

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 5.72

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I D

Ec/pH/Eh METER ID's 301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 14:17 6.99 3.98

pH AFTER MEASUREMENT 7.04 FOR STANDARD pH 7.0

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.0

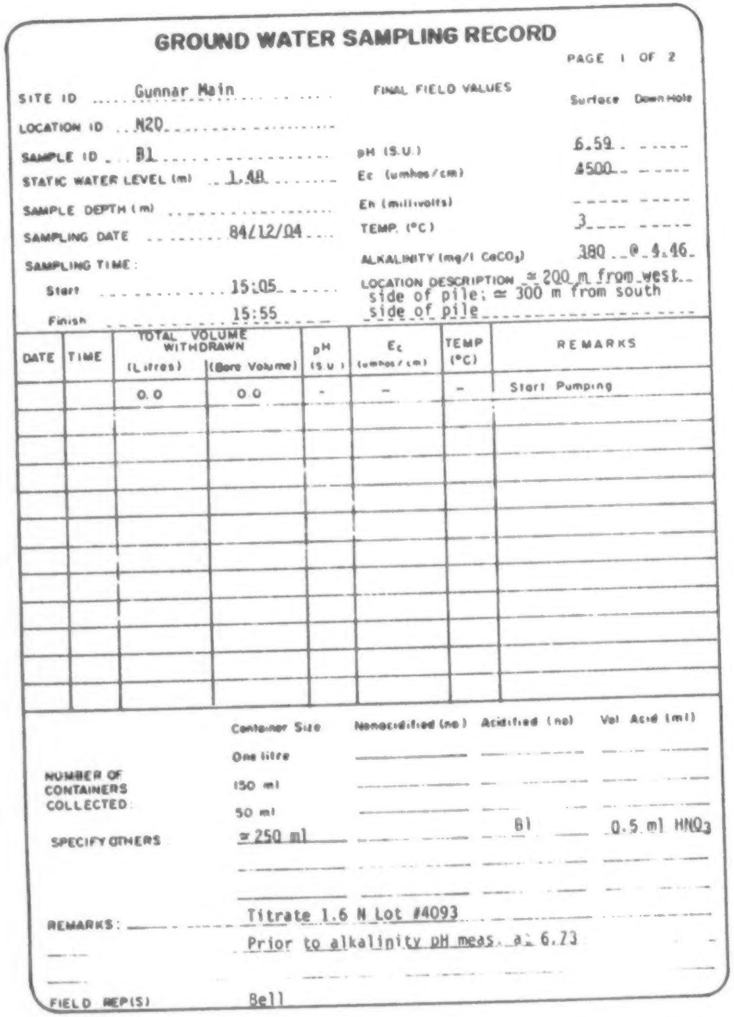
Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION			
LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	84/12/13	84/12/14	
METHOD OF SHIPMENT	Hand	Hand	
SAMPLE CLASSIFICATION	B1 & B2	B3 to B6	

NOTES N2B 84/12/04



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Main

LOCATION ID N20

SAMPLE ID B1

STATIC WATER LEVEL (m) 1.48

SAMPLE DEPTH (m)

SAMPLING DATE 84/12/04

SAMPLING TIME:

Start 15:05

Finish 15:55

FINAL FIELD VALUES

	Surface	Down Hole
pH (S.U.)	6.59	
Ec (umhos/cm)	4500	
Eh (millivolts)		
TEMP. (°C)	3	
ALKALINITY (mg/l CaCO$_3$)	380 @ 4.46	

LOCATION DESCRIPTION ≃ 200 m from west side of pile; ≃ 300 m from south side of pile

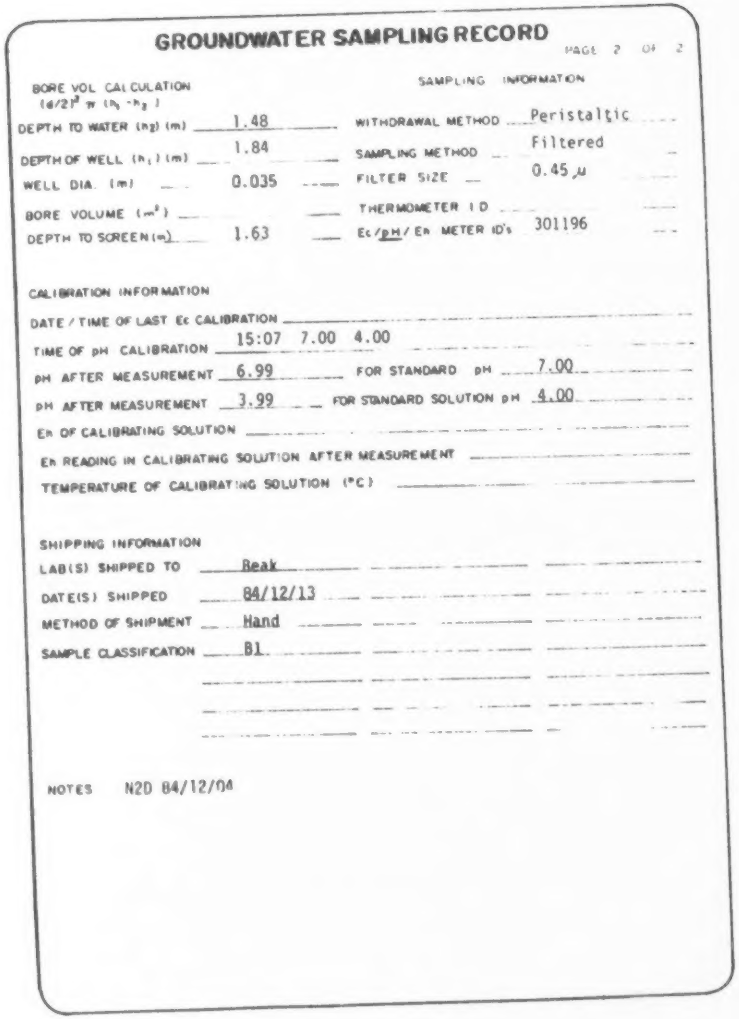
DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
							Start Pumping
		0.0	0.0	-	-	-	

	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	≃ 250 ml		B1	0.5 ml HNO_3

REMARKS: Titrate 1.6 N Lot #4093

Prior to alkalinity pH meas. a: 6.73

FIELD REP(S) Bell



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 1.48

DEPTH OF WELL (h_1) (m) 1.84

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 1.63

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I D

Ec/pH/Eh METER ID's 301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 15:07 7.00 4.00

pH AFTER MEASUREMENT 6.99 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.99 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO Beak

DATE(S) SHIPPED 84/12/13

METHOD OF SHIPMENT Hand

SAMPLE CLASSIFICATION B1

NOTES N2D 84/12/04

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Main

LOCATION ID N3AB

SAMPLE ID B1 to B4

STATIC WATER LEVEL (m) 2.65

SAMPLE DEPTH (m) 2.65 to 4.16

SAMPLING DATE 84/12/03

SAMPLING TIME:

Start 10:26

Finish 11:55

FINAL FIELD VALUES

	Surface	Down Hole
pH (S.U.)	5.47	
Ec (umhos/cm)	(Well 1) 7025	6500 (Well 2)
Eh (millivolts)		
TEMP. (°C)	5	
ALKALINITY (mg/l CaCO$_3$)	171 @ 4.51	

LOCATION DESCRIPTION Near North End of Gunnar Main

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		B4	2 ml HNO$_3$
	150 ml			
	250 ml	B1	B2	1 ml HNO$_3$
SPECIFY OTHERS	300 ml	B3		

REMARKS Depth of well = 4.16 m Sample freezing in discharge line
Lot #4093 1.6 N H$_2$SO$_4$ for Alk. Kit. Wells 1 & 2 at same
depth & location pH is 5.47 for both.

FIELD REP(S) Brinkman

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 2.65

DEPTH OF WELL (h_1) (m) 4.17

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 2.91

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I.D.

Ec/pH/Eh METER ID's

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 10:44

pH AFTER MEASUREMENT 7.04 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.98 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C) Assumed 5

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	84/12/13	84/12/14	
METHOD OF SHIPMENT	Hand	Hand	
SAMPLE CLASSIFICATION	B1 & B2	B3 & B4	

NOTES

Samples collected from all water from well.
Sample froze in discharge line, then sample shack placed directly over wells.
One filter used.
Two 500 ml containers filled with approx. 200 - 250 ml.
One 1000 ml container 9090 filled. 90%
One 1000 ml partially filled.

N3AB 84/12/03

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Main

LOCATION ID N3C

SAMPLE ID B1 to B3

STATIC WATER LEVEL (m) 1.52

SAMPLE DEPTH (m)

SAMPLING DATE 84/12/03

SAMPLING TIME

Start 14:30

Finish 15:21

FINAL FIELD VALUES	Surface	Down Hole
pH (S U)	5.49	
Ec (umhos/cm)	8000	
Eh (millivolts)		
TEMP (°C)	7	
ALKALINITY (mg/l CaCO$_3$)	179	@ 4.52

LOCATION DESCRIPTION ½ mile south of Granite Blowout N. End of Gunnar Main

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)		pH (S U)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		(Litres)	(Bore Volume)				
12/3		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre			
	150 ml			
	250 ml	B1	B2	1 ml HNO$_3$
SPECIFY OTHERS	500 ml		B3	1 ml HNO$_3$

REMARKS Titrate 1.6 Normal Lot #4093

FIELD REP(S) Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 1.52

DEPTH OF WELL (h_1) (m) 3.42±

WELL DIA (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 2.3±

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I D

Ec/pH/Eh METER ID's

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 14:43 7.01 4.01

pH AFTER MEASUREMENT 6.97 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	84/12/13	84/12/14	
METHOD OF SHIPMENT	Hand	Hand	
SAMPLE CLASSIFICATION	B1 & B2	B3	

NOTES

Two filters used.
Two 500 ml approx. half-filled.

N3C 84/12/03

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Main

LOCATION ID N3D

SAMPLE ID B1 to B3

STATIC WATER LEVEL (m) 1.12

SAMPLE DEPTH (m)

SAMPLING DATE 84/12/03

SAMPLING TIME:

Start 13:38

Finish 14:30

FINAL FIELD VALUES

	Surface	Down Hole
pH (S.U.)	5.95	
Ec (umhos/cm)	7500	
Eh (millivolts)		
TEMP. (°C)	5	
ALKALINITY (mg/l CaCO$_3$)	493 @ 4.55	

LOCATION DESCRIPTION ≈ ½ mile S. of Granite Blowout N. End of Gunnar Main

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
12/3	13:44	0 0	0 0	-	-	-	Start Pumping
	13:54			5.95		5	

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	750 ml		B3	.2 ml HNO$_3$
	250 ml	B1	B2	.1 ml HNO$_3$

REMARKS Titrate 1.6 N Lot #4093

FIELD REP(S) McKenzie

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 1.12

DEPTH OF WELL (h_1) (m) 2.17

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 1.01

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

Ec/pH/Eh METER ID's

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 13:52 6.98 4.0

pH AFTER MEASUREMENT 7.05 FOR STANDARD pH 7.0

pH AFTER MEASUREMENT 4.02 FOR STANDARD SOLUTION pH 4.0

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	84/12/13	84/12/14	
METHOD OF SHIPMENT	Hand	Hand	
SAMPLE CLASSIFICATION	B1 & B2	B3	

NOTES.

One Filter used.

Two 500 ml containers about half-filled.
N3D 84/12/03

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Main

LOCATION ID N3 EF

SAMPLE ID B1 to B3

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 84/12/07

SAMPLING TIME:

Start 11:00

Finish 14:45

FINAL FIELD VALUES

	Surface	Down Hole
pH (S.U.)	6.67	
Ec (umhos/cm)	3100	
Eh (millivolts)		
TEMP. (°C)	11 (1)	
ALKALINITY (mg/l CaCO$_3$)	444 @ 4.52	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS:	200 ml	B2	B1	0.5 HNO$_3$
	250 ml		B3	0.5 HNO$_3$

REMARKS: 1.6 Acid Lot #4093

Used 1 Filter

Combined N3E & N3E. Mostly N3E.

FIELD REP(S) Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION. $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 7.70 (E)

DEPTH OF WELL (h_1) (m) 13.74 (E)

WELL DIA. (m) 0.035

BORE VOLUME (m³)

DEPTH TO SCREEN (m) 13.35 (E)

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I D

Ec/pH/Eh METER ID's 301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 14:00

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	84/12/13	84/12/14	
METHOD OF SHIPMENT	Hand	Hand	
SAMPLE CLASSIFICATION	B1 & B2	B3	

NOTES (1) The water had warmed in the hut and the sample testing was done at this temperature.

N3EF 84/12/07

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Central

LOCATION ID N4A

SAMPLE ID B1 & B2

STATIC WATER LEVEL (m) 4.92

SAMPLE DEPTH (m)

SAMPLING DATE 84/12/08

SAMPLING TIME:

Start 12:15

Finish 12:50

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.57	-----
Ec (umhos/cm)	-----	-----
Eh (millivolts)	-----	-----
TEMP. (°C)	5	-----
ALKALINITY (mg/l CaCO$_3$)	246 @ 4.48	

LOCATION DESCRIPTION

Near Center of Gunnar Central

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
One litre			
150 ml			
250 ml	B2	B1	0.5 ml HNO$_3$

SPECIFY OTHERS

REMARKS 1.6 N Lot #4093

1 Filter

FIELD REP(S) Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 4.92

DEPTH OF WELL (h_1) (m) 5.92

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 5.41

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ.

THERMOMETER I.D.

Ec/pH/Eh METER ID's 301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 12:25

pH AFTER MEASUREMENT 7.01 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO Beak

DATE(S) SHIPPED 84/12/13

METHOD OF SHIPMENT Hand

SAMPLE CLASSIFICATION B1 & B2

NOTES N4A 84/12/08

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Central

LOCATION ID N48

SAMPLE ID B1

STATIC WATER LEVEL (m) 4.08

SAMPLE DEPTH (m)

SAMPLING DATE 84/12/08

SAMPLING TIME:

Start 14:35

Finish 15:30

FINAL FIELD VALUES

	Surface	Down Hole
pH (S.U.)	5.03	
Ec (umhos/cm)	4100	
Eh (millivolts)		
TEMP. (°C)	5	
ALKALINITY (mg/l CaCO$_3$)	99 @ 4.49	

LOCATION DESCRIPTION Near Center of Gunnar Central Tailings Pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

	Container Size	Nonacidified (no.)	Acidified (no.)	Vol. Acid (ml)
	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	20 ml		B1	0.25 ml HNO$_3$

REMARKS: 1.6 N Lot #4093

Used 1 Filter

FIELD REP(S) Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h$_2$) (m) 4.08

DEPTH OF WELL (h$_1$) (m) 4.42

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 3.87

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I.D.

Ec/pH/Eh METER ID's 301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 2:50

pH AFTER MEASUREMENT 6.99 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO Beak

DATE(S) SHIPPED 84/12/13

METHOD OF SHIPMENT Hand

SAMPLE CLASSIFICATION B1

NOTES: N48 84/12/08

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Central

LOCATION ID N4C

SAMPLE ID B1 & B2

STATIC WATER LEVEL (m) 1.99

SAMPLE DEPTH (m)

SAMPLING DATE 84/12/08

SAMPLING TIME:

Start 13:00

Finish 13:40

FINAL FIELD VALUES

	Surface	Down Hole
pH (S U)	5.94	
Ec (umhos/cm)	4600	
Eh (millivolts)		
TEMP. (°C)	5	

ALKALINITY (mg/l $CaCO_3$) 185 @ 4.51

LOCATION DESCRIPTION Near Center of Gunnar Central Tailings Pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S U)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
One litre			
150 ml			
250 ml	B2	B1	0.5 ml HNO_3

SPECIFY OTHERS

REMARKS 1.6 N Lot #4093

Used 1 Filter

FIELD REP(S) Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 1.99

DEPTH OF WELL (h_1) (m) 2.82

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 2.33

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I D

Ec/pH/Eh METER ID's 301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 13:20

pH AFTER MEASUREMENT 6.99 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.02 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO Beak

DATE(S) SHIPPED 84/12/13

METHOD OF SHIPMENT Hand

SAMPLE CLASSIFICATION B1 & B2

NOTES N4C 84/12/08

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar Central

LOCATION ID N4D

SAMPLE ID B1 & B2

STATIC WATER LEVEL (m) 1.66

SAMPLE DEPTH (m)

SAMPLING DATE 84/12/08

SAMPLING TIME:

Start 13:45

Finish 14:30

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	4.88	
Ec (umhos/cm)	11,900	
Eh (millivolts)		
TEMP. (°C)	5	
ALKALINITY (mg/l CaCO$_3$)	28 @ 4.50	

LOCATION DESCRIPTION Near Center of Gunnar Central Tailings Pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
One litre			
150 ml			
50 ml			
SPECIFY OTHERS 200 ml	B2	B1	0.5 ml HNO$_3$

REMARKS: 1.6 N Lot #4093
Used 1 Filter

FIELD REP(S) Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 1.66

DEPTH OF WELL (h_1) (m) 2.17

WELL DIA (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 1.28

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I.D.

Ec/pH/Eh METER ID's 301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 13:55

pH AFTER MEASUREMENT 6.97 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.96 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO Beak

DATE(S) SHIPPED 84/12/13

METHOD OF SHIPMENT Hand

SAMPLE CLASSIFICATION B1 & B2

NOTES N4D 84/12/08

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Langley Bay
LOCATION ID N5A
SAMPLE ID B1 to B3
STATIC WATER LEVEL (m) 11.25
SAMPLE DEPTH (m)
SAMPLING DATE 84/12/19
SAMPLING TIME:
Start 13:50
Finish 14:30

FINAL FIELD VALUES

	Surface	Down Hole
pH (S.U.)	6.50	
Ec (umhos/cm)	3000	
Eh (millivolts)		
TEMP. (°C)	6	
ALKALINITY (mg/l CaCO$_3$)	178.0	4.52

LOCATION DESCRIPTION
Due west of Gunnar Central

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED	Container Size	Nonacidified (no.)	Acidified (no.)	Vol. Acid (ml)
	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml	B2	B1	0.5 ml HNO$_3$
	200 ml		B3	0.5 ml HNO$_3$

REMARKS 1.6 N. Lot #4093
Used 1 Filter

FIELD REP(S) Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m) 12.18
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 11.67

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailed
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
Ec/pH/Eh METER ID's 301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION 14:05
pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC
DATE(S) SHIPPED	84/12/13	84/12/14
METHOD OF SHIPMENT	Hand	Hand
SAMPLE CLASSIFICATION	B1 & B2	B3

NOTES N5A 84/12/19

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Langley Bay

LOCATION ID N5B

SAMPLE ID B1

STATIC WATER LEVEL (m) 3.46

SAMPLE DEPTH (m)

SAMPLING DATE 84/12/09

SAMPLING TIME:

Start 12:45

Finish 13:30

FINAL FIELD VALUES

	Surface	Down Hole
pH (S.U.)	5.95	
Ec (umhos/cm)	8000	
Eh (millivolts)		
TEMP (°C)	7	
ALKALINITY (mg/l $CaCO_3$)	133 @ 4.49	

LOCATION DESCRIPTION Due west of Gunnar Central

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	E_c (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
One litre			
150 ml			
50 ml			
SPECIFY OTHERS: 300 ml		B1	0.5 ml HNO_3

REMARKS: 1.6 N Lot #4093

Used 1 Filter

FIELD REP(S) Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION. $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 3.91

WELL DIA (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 3.36

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I D

Ec/pH/Eh METER ID's 301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 13:00

pH AFTER MEASUREMENT 7.04 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.03 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO Beak

DATE(S) SHIPPED 84/12/13

METHOD OF SHIPMENT Hand

SAMPLE CLASSIFICATION B1

NOTES: N5B 84/12/09

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Langley Bay

LOCATION ID: N5C

SAMPLE ID: B1 & B2

STATIC WATER LEVEL (m): 1.80

SAMPLE DEPTH (m):

SAMPLING DATE: 84/12/09

SAMPLING TIME:

Start: 11:45

Finish: 12:30

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.18	-----
Ec (umhos/cm)	5000	-----
Eh (millivolts)	-----	-----
TEMP. (°C)	6	-----
ALKALINITY (mg/l $CaCO_3$)	166 @ 4.51	

LOCATION DESCRIPTION: Due west of Gunnar Central

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	200 ml	B2	B1	0.5 ml HNO_3

REMARKS: 1.6 N Lot #4093

Used 1 Filter

FIELD REP(S): Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m):

DEPTH OF WELL (h_1) (m): 2.60

WELL DIA. (m): 0.035

BORE VOLUME (m^3):

DEPTH TO SCREEN (m): 2.10

SAMPLING INFORMATION

WITHDRAWAL METHOD: Peristaltic

SAMPLING METHOD: Filtered

FILTER SIZE: 0.45 µ

THERMOMETER I.D.:

Ec/pH/Eh METER ID's: 301196

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION:

TIME OF pH CALIBRATION: 11:55

pH AFTER MEASUREMENT: 7.00 FOR STANDARD pH: 7.00

pH AFTER MEASUREMENT: 4.00 FOR STANDARD SOLUTION pH: 4.00

Eh OF CALIBRATING SOLUTION:

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT:

TEMPERATURE OF CALIBRATING SOLUTION (°C):

SHIPPING INFORMATION

LAB(S) SHIPPED TO: Beak

DATE(S) SHIPPED: 84/12/13

METHOD OF SHIPMENT: Hand

SAMPLE CLASSIFICATION: B1 & B2

NOTES: N5C 84/12/09

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Distilled Water
LOCATION ID: NA
SAMPLE ID B1, B2, B3
STATIC WATER LEVEL (m) NA
SAMPLE DEPTH (m) NA
SAMPLING DATE 85/03/22
SAMPLING TIME:
Start 10:00
Finish 10:30

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)		
Ec (umhos/cm)		
Eh (millivolts)		
TEMP. (°C)		
ALKALINITY (mg/l CaCO$_3$)		

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	–	Start Pumping

NUMBER OF CONTAINERS COLLECTED:	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre		B3	2 HNO$_3$
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	250 ml		B2	1.5 HNO$_3$

REMARKS: Filter appartus and sampling hose flushed with distilled water and samples collected. Used 1 filter.

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m)
WELL DIA. (m)
BORE VOLUME (m^3)
DEPTH TO SCREEN (m)

SAMPLING INFORMATION
WITHDRAWAL METHOD Peristaltic
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's
Ec METER I.D.

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION
pH AFTER MEASUREMENT FOR STANDARD pH
pH AFTER MEASUREMENT FOR STANDARD SOLUTION pH
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	Express Airborne	Hand	
METHOD OF SHIPMENT	85/03/29	85/03/29	
SAMPLE CLASSIFICATION	B1, B2	B3	

NOTES: NA 85/03/22

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: NIC
SAMPLE ID B1 to B6
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 85/03/10
SAMPLING TIME:
Start 10:00
Finish. 11:30

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.34	
Ec (umhos/cm)	3750	
Eh (millivolts)		
TEMP. (°C)	5	
ALKALINITY (mg/l CaCO$_3$)	674	@ 4.5
	682	@ 4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)		pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		(Litres)	(Bore Volume)				
		0.0	0.0	-	–	–	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B6	3 ml HNO$_3$
	150 ml			
	50 ml			
SPECIFY OTHERS.	500 ml		B3, B4, B5	2.5 ml each
	250 ml		B2	2 ml
	500 ml	B1		

REMARKS: Used 2 filters. 1.6 N Lot #4240. Salinity 3.0%

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h$_2$) (m) 5.98
DEPTH OF WELL (h$_1$) (m) 10.18
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 9.67

SAMPLING INFORMATION
WITHDRAWAL METHOD Peristaltic
SAMPLING METHOD Filtered
FILTER SIZE 0.45 μ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.
TIME OF pH CALIBRATION 10:20
pH AFTER MEASUREMENT 6.99 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA
TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	Monenco
DATE(S) SHIPPED	85/03/25	85/03/25	85/03/25
METHOD OF SHIPMENT	Express Airborne	Hand	Express Airborne
SAMPLE CLASSIFICATION	B1, B2	B3, B4, B1A, B2A	B5, B6 (to be combined)

NOTES: Piezometer #N1D 5.93 m to W/L
6.03 m to Bottom
Not enough water to sample

NIC 86/03/10

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: N1E

SAMPLE ID: B1 to B4

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE: 85/03/29

SAMPLING TIME:

Start: 10:00

Finish: 11:40

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.43	
Ec (umhos/cm)	1940	1820
Eh (millivolts)		
TEMP. (°C)	4	1
ALKALINITY (mg/l $CaCO_3$)	164	@4.5
	167	@4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)		pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		(Litres)	(Bore Volume)				
		0.0	0.0	-	–	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B3	3 ml HNO_3
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	250 ml		B2	2 ml
	500 ml		B4	2 ml

REMARKS: Used 3 filters. 1.6N Lot #4310, 1% Salinity downhole

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m): 6.09

DEPTH OF WELL (h_1) (m): 8.15

WELL DIA. (m): 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m): 7.79

SAMPLING INFORMATION

WITHDRAWAL METHOD: Bailed

SAMPLING METHOD: Filtered

FILTER SIZE: 0.45 μ

THERMOMETER I.D.

pH / Eh METER #'s: 301196

Ec METER I.D.: 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION: 85/02/26 - P.M.

TIME OF pH CALIBRATION: 10:20

pH AFTER MEASUREMENT: 7.00 FOR STANDARD pH: 7.00

pH AFTER MEASUREMENT: 10.01 FOR STANDARD SOLUTION pH: 10.00

Eh OF CALIBRATING SOLUTION: NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT: NA

TEMPERATURE OF CALIBRATING SOLUTION (°C): NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/04/02	85/04/02	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES: N1E 85/03/29

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: N2E
SAMPLE ID B1
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 85/03/25
SAMPLING TIME:
Start 12:30
Finish. 13:10

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.62	
Ec (umhos/cm)		2470
Eh (millivolts)		
TEMP. (°C)	8	2
ALKALINITY (mg/l $CaCO_3$)	610 @ 4.5 621 @ 4.2	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	E_c (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	100 ml		B1	1 ml

REMARKS: Used 1 filter. 1.6 N Lot #4310, 2% Salinity downhole

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m) 7.60
DEPTH OF WELL (h_1) (m) 8.09
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 7.60

SAMPLING INFORMATION
WITHDRAWAL METHOD Bailed
SAMPLING METHOD Filtered
FILTER SIZE 0.45 μ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.
TIME OF pH CALIBRATION 12:50
pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 3.98 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA
TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION
LAB(S) SHIPPED TO BEAK
DATE(S) SHIPPED 85/03/29
METHOD OF SHIPMENT Express Airborne
SAMPLE CLASSIFICATION B1

NOTES N2E 85/03/25

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: N2G

SAMPLE ID: B1 to B4

STATIC WATER LEVEL (m):

SAMPLE DEPTH (m):

SAMPLING DATE: 85/03/25

SAMPLING TIME:

Start: 11:20

Finish: 12:20

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.41	
Ec (umhos/cm)	2950	2030
Eh (millivolts)		
TEMP. (°C)	5	0
ALKALINITY (mg/l $CaCO_3$)	600	@ 4.5
	609	@ 4.2

LOCATION DESCRIPTION:

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B3, B4	3 ml HNO_3
	150 ml			
	50 ml			
SPECIFY OTHERS.	500 ml	B1		
	250 ml		B2	1.5 ml

REMARKS: Used 1 Filter. 1.6 N Lot #4310, 2% Salinity downhole

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m): 1.32

DEPTH OF WELL (h_1) (m): 5.95

WELL DIA. (m): 0.035

BORE VOLUME (m^3):

DEPTH TO SCREEN (m): 5.39

SAMPLING INFORMATION

WITHDRAWAL METHOD: Peristaltic

SAMPLING METHOD: Filtered

FILTER SIZE: 0.45 µ

THERMOMETER I.D.:

pH / Eh METER ID's: 301196

Ec METER I.D.: 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION: 85/02/26 - P.M.

TIME OF pH CALIBRATION: 11:30

pH AFTER MEASUREMENT: 7.01 FOR STANDARD pH: 7.00

pH AFTER MEASUREMENT: 4.01 FOR STANDARD SOLUTION pH: 4.00

Eh OF CALIBRATING SOLUTION: NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT: NA

TEMPERATURE OF CALIBRATING SOLUTION (°C): NA

SHIPPING INFORMATION			
LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/03/29	85/03/29	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES: N2G 85/03/25

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: N2H

SAMPLE ID: B1 to B4

STATIC WATER LEVEL (m):

SAMPLE DEPTH (m):

SAMPLING DATE: 85/03/25

SAMPLING TIME:

Start: 10:15

Finish: 11:15

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.41	
E_c (umhos/cm)	2670	1950
E_h (millivolts)		
TEMP. (°C)	9	1
ALKALINITY (mg/l $CaCO_3$)	289 @	4.5
	296 @	4.2

LOCATION DESCRIPTION:

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	E_c (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	–	Start Pumping

NUMBER OF CONTAINERS COLLECTED	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
	One litre		B3	2.5 ml HNO_3
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1		
	250 ml		B2	1 ml
	500 ml		B4	1.5 ml

REMARKS: Used 1 filter. 1.6 N Lot #4310. 2% Salinity downhole

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m): 1.24

DEPTH OF WELL (h_1) (m): 3.58

WELL DIA. (m): 0.035

BORE VOLUME (m^3):

DEPTH TO SCREEN (m): 3.13

SAMPLING INFORMATION

WITHDRAWAL METHOD: Peristaltic

SAMPLING METHOD: Filtered

FILTER SIZE: 0.45 μ

THERMOMETER I.D.:

pH / E_h METER ID's: 301196

E_c METER I.D.: 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST E_c CALIBRATION: 85/02/26 - P.M.

TIME OF pH CALIBRATION: 10:30

pH AFTER MEASUREMENT: 6.99 FOR STANDARD pH: 7.00

pH AFTER MEASUREMENT: 4.02 FOR STANDARD SOLUTION pH: 4.00

E_h OF CALIBRATING SOLUTION: NA

E_h READING IN CALIBRATING SOLUTION AFTER MEASUREMENT: NA

TEMPERATURE OF CALIBRATING SOLUTION (°C): NA

SHIPPING INFORMATION			
LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/03/29	85/03/29	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES: N2H 85/03/25

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: N2I

SAMPLE ID: B1 to B4

STATIC WATER LEVEL (m):

SAMPLE DEPTH (m):

SAMPLING DATE: 85/03/25

SAMPLING TIME:

Start: 09:00

Finish: 10:15

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.66	
Ec (umhos/cm)		2060
Eh (millivolts)		
TEMP. (°C)	7	0
ALKALINITY (mg/l $CaCO_3$)	437 @ 4.5 444 @ 4.2	

LOCATION DESCRIPTION:

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
One litre		B4	2.5 ml HNO_3
150 ml			
50 ml			
SPECIFY OTHERS: 500 ml	B1		
250 ml		B2	1 ml
500 ml		B3	1.5 ml

REMARKS: Used 1 filter. 1.6 N Lot #4310. 2% Salinity downhole

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m): 1.30

DEPTH OF WELL (h_1) (m): 2.69

WELL DIA. (m): 0.035

BORE VOLUME (m^3):

DEPTH TO SCREEN (m): 2.19

SAMPLING INFORMATION

WITHDRAWAL METHOD: Peristaltic

SAMPLING METHOD: Filtered

FILTER SIZE: 0.45 µ

THERMOMETER I.D.:

pH / Eh METER ID's: 301196

Ec METER I.D.: 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION: 85/02/26 - P.M.

TIME OF pH CALIBRATION: 09:20

pH AFTER MEASUREMENT: 6.97 FOR STANDARD pH: 7.00

pH AFTER MEASUREMENT: 3.98 FOR STANDARD SOLUTION pH: 4.00

Eh OF CALIBRATING SOLUTION: NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT: NA

TEMPERATURE OF CALIBRATING SOLUTION (°C): NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/03/29	85/03/29	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES: N2I 85/03/25

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: N6A

SAMPLE ID B1, B2, B4

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/03/12

SAMPLING TIME:

Start 15:30

Finish 16:30

FINAL FIELD VALUES	Surface		Down Hole
pH (S.U.)	7.54		
Ec (umhos/cm)	1210		1220
Eh (millivolts)			
TEMP. (°C)	4		3
ALKALINITY (mg/l $CaCO_3$)	373	@	4.5
	378	@	4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN		pH	Ec	TEMP	REMARKS
		(Litres)	(Bore Volume)	(S.U.)	(umhos/cm)	(°C)	
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		B4	3 ml HNO_3
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1		
	250 ml		B2	2 ml

REMARKS: Used 1 filter. 1.6 N Lot #4240, 1% Salinity downhole

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 9.86

DEPTH OF WELL (h_1) (m) 11.63

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 11.00

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailed

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 15:45

pH AFTER MEASUREMENT 6.97 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 9.96 FOR STANDARD SOLUTION pH 10.00

Eh OF CALIBRATING SOLUTION NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/03/25	85/03/25	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B4	

NOTES N6A 85/03/12

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: N6B

SAMPLE ID: B1 to B4

STATIC WATER LEVEL (m) ______

SAMPLE DEPTH (m) ______

SAMPLING DATE: 85/03/12

SAMPLING TIME:

Start: 14:15

Finish: 15:25

LOCATION DESCRIPTION ______

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.23	
Ec (umhos/cm)	2780	2480
Eh (millivolts)		
TEMP. (°C)	4	2
ALKALINITY (mg/l $CaCO_3$)	225	@ 4.5
	230	@ 4.2

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
One litre		B3	3 ml HNO_3
150 ml			
50 ml			
SPECIFY OTHERS: 250 ml		B2	2 ml HNO_3
500 ml	B1		
250 ml		B4	1 ml HNO_3

REMARKS: Used 1 filter. 1.6 N Lot #4240, 2% Salinity downhole

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m): 2.79

DEPTH OF WELL (h_1) (m): 5.76

WELL DIA. (m): 0.035

BORE VOLUME (m^3) ______

DEPTH TO SCREEN (m): 5.15

SAMPLING INFORMATION

WITHDRAWAL METHOD: Peristaltic

SAMPLING METHOD: Filtered

FILTER SIZE: 0.45 µ

THERMOMETER I.D. ______

pH / Eh METER ID's: 301196

Ec METER I.D.: 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION: 85/02/26 - P.M.

TIME OF pH CALIBRATION: 14:30

pH AFTER MEASUREMENT: 7.01 FOR STANDARD pH: 7.00

pH AFTER MEASUREMENT: 3.98 FOR STANDARD SOLUTION pH: 4.00

Eh OF CALIBRATING SOLUTION: NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT: NA

TEMPERATURE OF CALIBRATING SOLUTION (°C): NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/03/25	85/03/25	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES: N6B 85/03/12

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: N6C
SAMPLE ID: B1 to B4
STATIC WATER LEVEL (m):
SAMPLE DEPTH (m):
SAMPLING DATE: 85/03/12
SAMPLING TIME:
Start: 13:00
Finish: 14:10

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	5.84	
Ec (umhos/cm)		3230
Eh (millivolts)		
TEMP. (°C)	4	0
ALKALINITY (mg/l $CaCO_3$)	171	@4.5
	177	@4.2

LOCATION DESCRIPTION:

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		B3	3 ml HNO_3
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml		B2	2 ml
	500 ml	B1		
	700 ml		B4	2 ml HNO_3

REMARKS: Used 1 filter. 1.6 N Lot #4240. 3% Salinity downhole

FIELD REP(S): R. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m): 1.30
DEPTH OF WELL (h_1) (m): 4.39
WELL DIA. (m): 0.035
BORE VOLUME (m^3):
DEPTH TO SCREEN (m): 3.93

SAMPLING INFORMATION
WITHDRAWAL METHOD: Peristaltic
SAMPLING METHOD: Filtered
FILTER SIZE: 0.45 µ
THERMOMETER I.D.:
pH / Eh METER ID's: 301196
Ec METER I.D.: 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION: 85/02/26 - P.M.
TIME OF pH CALIBRATION: 13:05
pH AFTER MEASUREMENT: 7.00 FOR STANDARD pH: 7.00
pH AFTER MEASUREMENT: 3.97 FOR STANDARD SOLUTION pH: 4.00
Eh OF CALIBRATING SOLUTION: NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT: NA
TEMPERATURE OF CALIBRATING SOLUTION (°C): NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/03/25	85/03/25	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES: N6C 85/03/12

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: N60

SAMPLE ID: B1 to B4

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/03/12

SAMPLING TIME:

Start 10:20

Finish 11:30

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	5.77	
Ec (umhos/cm)	3150	3240
Eh (millivolts)		
TEMP. (°C)	3	
ALKALINITY (mg/l $CaCO_3$)	112 @	4.5
	117 @	4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B3	4 ml HNO_3
	150 ml			
	50 ml			
SPECIFY OTHERS:	250 ml		B2	2 ml HNO_3
	500 ml	B1		
	250 ml		B4	2 ml HNO_3

REMARKS: Used 1 filter. 1.6 N Lot #4240. 3% Salinity downhole

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 1.30

DEPTH OF WELL (h_1) (m) 3.63

WELL DIA (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 2.97

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 10:35

pH AFTER MEASUREMENT 6.99 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.99 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	BBT - EDMONTON
DATE(S) SHIPPED	85/03/25	85/03/25	85/03/25
METHOD OF SHIPMENT	Express Airborne	Hand	Express Airborne
SAMPLE CLASSIFICATION	B1, B2	B3	B4

NOTES: N60 95/03/12

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: N6E
SAMPLE ID B1, B2
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 85/03/12
SAMPLING TIME:
Start 08:50
Finish 10:00

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.18	
Ec (umhos/cm)		2600
Eh (millivolts)		
TEMP. (°C)	4	1
ALKALINITY (mg/l $CaCO_3$)	235	@ 4.50
	240	@ 4.20

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS:	250 ml		B2	2 ml
	500 ml	B1		

REMARKS: Used 1 filter. 1.6 N Lot #4240

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m) 1.20
DEPTH OF WELL (h_1) (m) 2.51
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 1.95

SAMPLING INFORMATION
WITHDRAWAL METHOD Peristaltic
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.
TIME OF pH CALIBRATION 09:15
pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.02 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA
TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK		
DATE(S) SHIPPED	85/03/25		
METHOD OF SHIPMENT	Express Airborne		
SAMPLE CLASSIFICATION	B1, B2		

NOTES N6E 85/03/12

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: GM2B
SAMPLE ID: B1, B2, B3
STATIC WATER LEVEL (m):
SAMPLE DEPTH (m):
SAMPLING DATE: 85/03/30
SAMPLING TIME:
Start 12:30
Finish 13:40

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.65	
Ec (umhos/cm)	3150	
Eh (millivolts)		
TEMP. (°C)	6	
ALKALINITY (mg/l CaCO$_3$)	777 @ 4.5	
	785 @ 4.2	

LOCATION DESCRIPTION:

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B3	3 ml
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	250 ml		B2	2 ml

REMARKS: Used 2 filters. 1.6 N Lot #4310, 2.5% Salinity

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m) 4.11
DEPTH OF WELL (h_1) (m) 7.55
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 6.97

SAMPLING INFORMATION
WITHDRAWAL METHOD Peristaltic
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.
TIME OF pH CALIBRATION 12:50
pH AFTER MEASUREMENT 6.96 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA
TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/04/02	85/04/02	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3	

NOTES: Piezometer #GM2C W/L - 4.03
4.19 m bottom
Not enough water to sample

GM2B 85/03/30

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gummar Main

LOCATION ID: GM3B

SAMPLE ID B1

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/03/30

SAMPLING TIME:

Start 11:30

Finish 12:05

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.22	
Ec (umhos/cm)	3380	3150
Eh (millivolts)		
TEMP. (°C)	6	1
ALKALINITY (mg/l $CaCO_3$)	316	@ 4.5
	326	@ 4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	200 ml		B1	2 ml

REMARKS: Used 1 filter. 1.6N Lot #4310, 3% Salinity downhole

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 9.83

DEPTH OF WELL (h_1) (m) 10.41

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 9.90

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailed

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 11:45

pH AFTER MEASUREMENT 7.01 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.99 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK		
DATE(S) SHIPPED	85/04/02		
METHOD OF SHIPMENT	Express Airborne		
SAMPLE CLASSIFICATION	B1		

NOTES: GM3B 85/03/30

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: GM3C
SAMPLE ID B1 to B4
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 85/03/30
SAMPLING TIME:
Start 10:10
Finish. 11:15

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.55	
Ec (umhos/cm)	2930	2320
Eh (millivolts)		
TEMP. (°C)	8	2
ALKALINITY (mg/l $CaCO_3$)	444	@ 4.5
	454	@ 4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	–	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B3	3 ml
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	250 ml		B2	2 ml
	500 ml		B4	2 ml

REMARKS: Used 1 filter. 1.6 N Lot #4310, 2% Salinity downhole

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m) 2.29
DEPTH OF WELL (h_1) (m) 4.79
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 4.14

SAMPLING INFORMATION
WITHDRAWAL METHOD Peristaltic
SAMPLING METHOD Filtered
FILTER SIZE 0.45 μ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.
TIME OF pH CALIBRATION 10:20
pH AFTER MEASUREMENT 6.99 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 3.99 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA
TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	Monenco
DATE(S) SHIPPED	85/04/02	85/04/02	85/04/02
METHOD OF SHIPMENT	Express Airborne	Hand	Express Airborne
SAMPLE CLASSIFICATION	B1, B2	B3, B4	B3, B4*
		B1, B2 *	

*NOTES: Supplementary samples taken as check samples labelled
GM3F B1 (500 ml NA), B2 (250 ml - 2 ml HNO_3), B3 (1 litre 3 ml HNO_3)
B4 (500 ml - 2 ml HNO_3)

GM3F B1 and B2 shipped to SRC

GM3F B3 and B4 shipped to Monenco

GM3C 85/03/30

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM4B

SAMPLE ID: B1 to B3 (two sets)

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/03/20

SAMPLING TIME:

Start 13:10

Finish 14:10

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.58	
Ec (umhos/cm)	1880	1680
Eh (millivolts)		
TEMP. (°C)	4	1
ALKALINITY (mg/l $CaCO_3$)	427	@4.5
	434	@4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml		2- B2	2 ml HNO_3 each
	500 ml	2-B1		
	500 ml		2- B3	1.5 ml HNO_3 each

REMARKS: Used 2 filters. 1.6 N Lot #4240. 1* Salinity downhole

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 1.97

DEPTH OF WELL (h_1) (m) 5.20

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 4.67

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 13:20

pH AFTER MEASUREMENT 7.02 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.98 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION NA

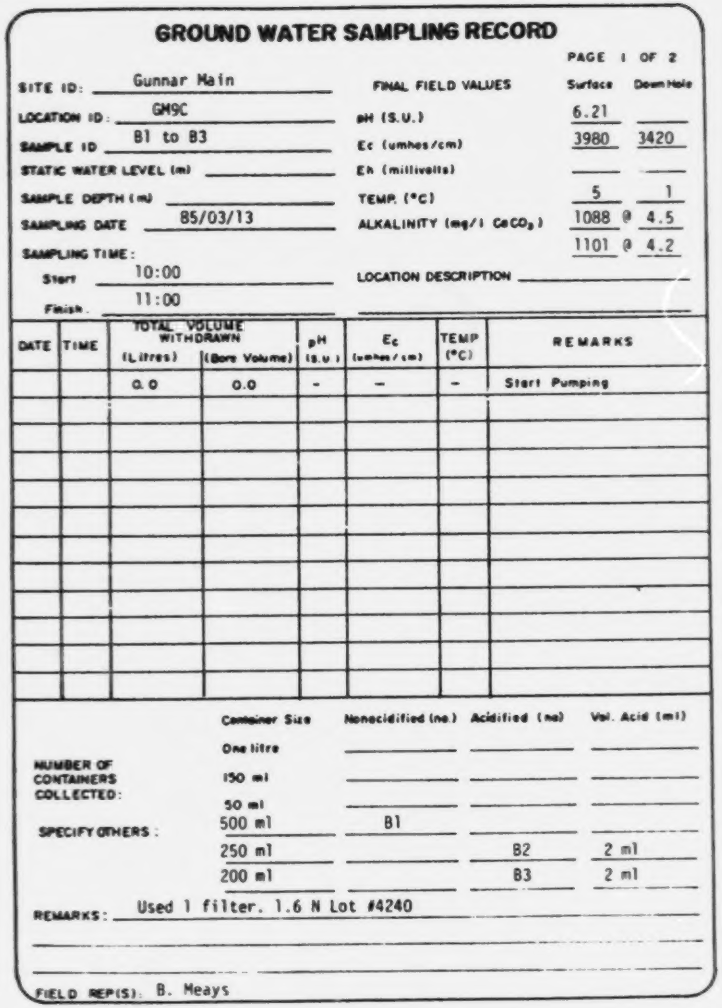
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/03/29	85/03/29	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3	
	B1, B2 *	B3 *	

*NOTES: Duplicate samples with designation
GM4D - B1 to B3 also collected
GM4D - B1 and B2 shipped to BEAK
GM4D - B3 shipped to SRC
GM4B 85/03/20



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM9C

SAMPLE ID B1 to B3

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/03/13

SAMPLING TIME:

Start 10:00

Finish. 11:00

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.21	
Ec (umhos/cm)	3980	3420
Eh (millivolts)		
TEMP. (°C)	5	1
ALKALINITY (mg/l $CaCO_3$)	1088 @ 4.5	
	1101 @ 4.2	

LOCATION DESCRIPTION

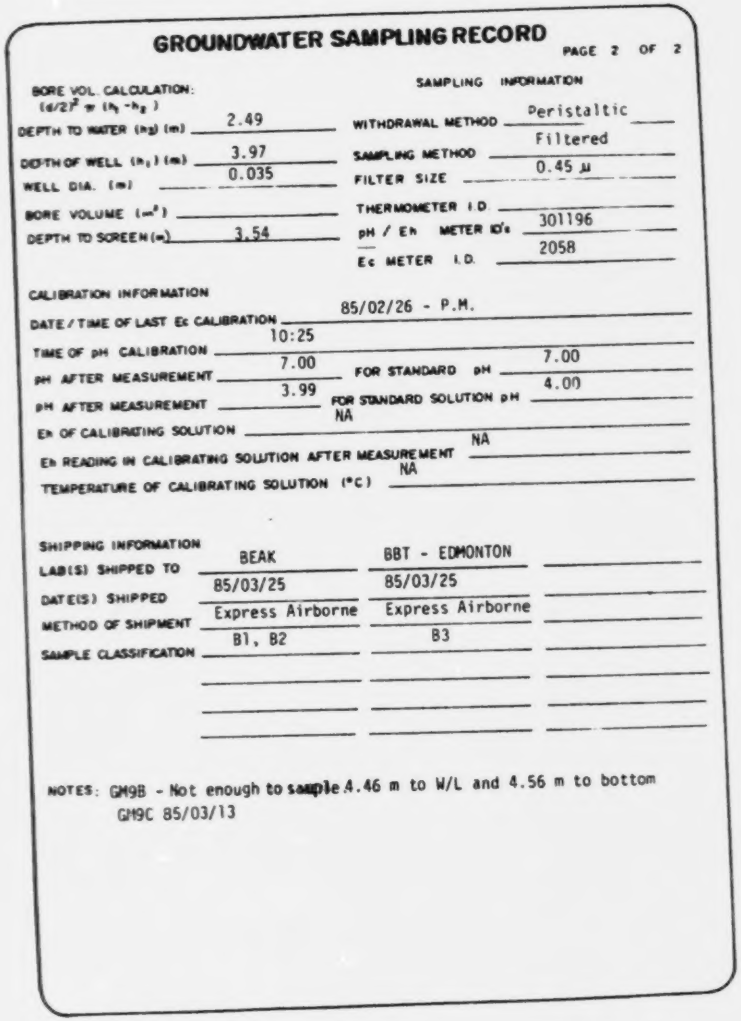
DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	250 ml		B2	2 ml
	200 ml		B3	2 ml

REMARKS: Used 1 filter. 1.6 N Lot #4240

FIELD REP(S): B. Meays



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_t - h_g)$

DEPTH TO WATER (h_g) (m) 2.49

DEPTH OF WELL (h_t) (m) 3.97

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 3.54

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE/TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 10:25

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.99 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	BBT - EDMONTON	
DATE(S) SHIPPED	85/03/25	85/03/25	
METHOD OF SHIPMENT	Express Airborne	Express Airborne	
SAMPLE CLASSIFICATION	B1, B2	B3	

NOTES: GM9B - Not enough to sample 4.46 m to W/L and 4.56 m to bottom
GM9C 85/03/13

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: GM12A
SAMPLE ID B1
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 85/03/24
SAMPLING TIME:
Start 10:00
Finish 10:45

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.24	
Ec (umhos/cm)	3430	3080
Eh (millivolts)		
TEMP. (°C)	7	4
ALKALINITY (mg/l $CaCO_3$)	1085	@ 4.5
	1098	@ 4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
One litre			
150 ml			
50 ml			
SPECIFY OTHERS: 450 ml	B1		

REMARKS: Used 1 filter. 1.6 N Lot #4240. 3% Salinity

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

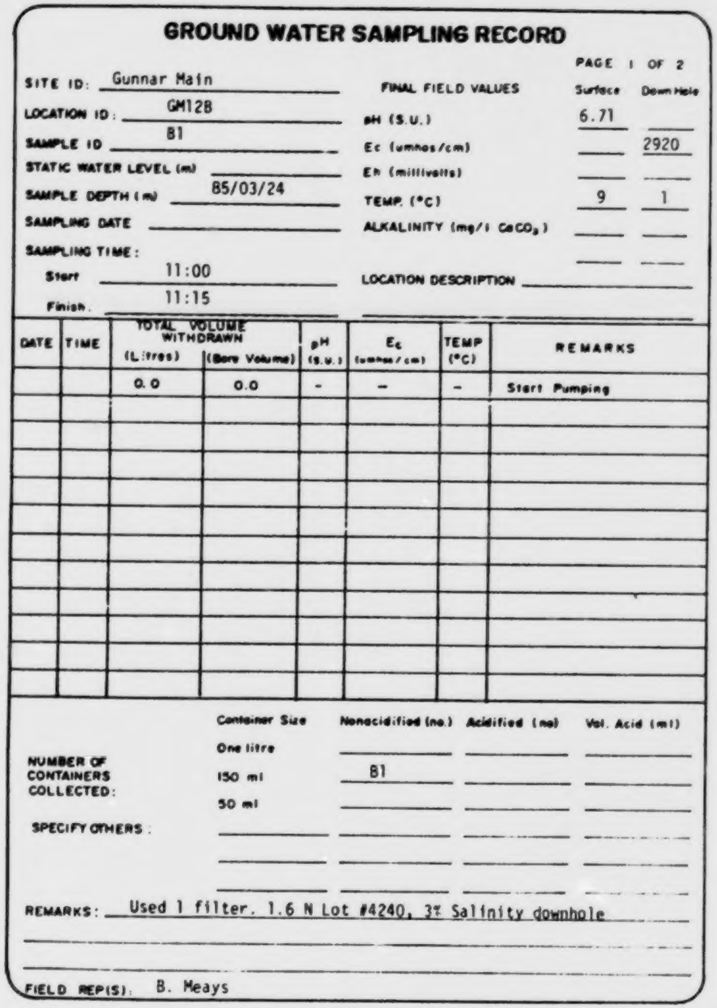
BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m) 2.66
DEPTH OF WELL (h_1) (m) 3.40
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 3.00

SAMPLING INFORMATION
WITHDRAWAL METHOD Peristaltic
SAMPLING METHOD Filtered
FILTER SIZE 0.45 μ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.
TIME OF pH CALIBRATION 10:15
pH AFTER MEASUREMENT 6.98 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 3.96 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA
TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION
LAB(S) SHIPPED TO BEAK
DATE(S) SHIPPED 85/03/29
METHOD OF SHIPMENT Express Airborne
SAMPLE CLASSIFICATION B1

NOTES: GM12A 85/03/24



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM12B

SAMPLE ID B1

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m) 85/03/24

SAMPLING DATE

SAMPLING TIME:

Start 11:00

Finish. 11:15

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.71	
Ec (umhos/cm)		2920
Eh (millivolts)		
TEMP. (°C)	9	1
ALKALINITY (mg/l CaCO$_3$)		

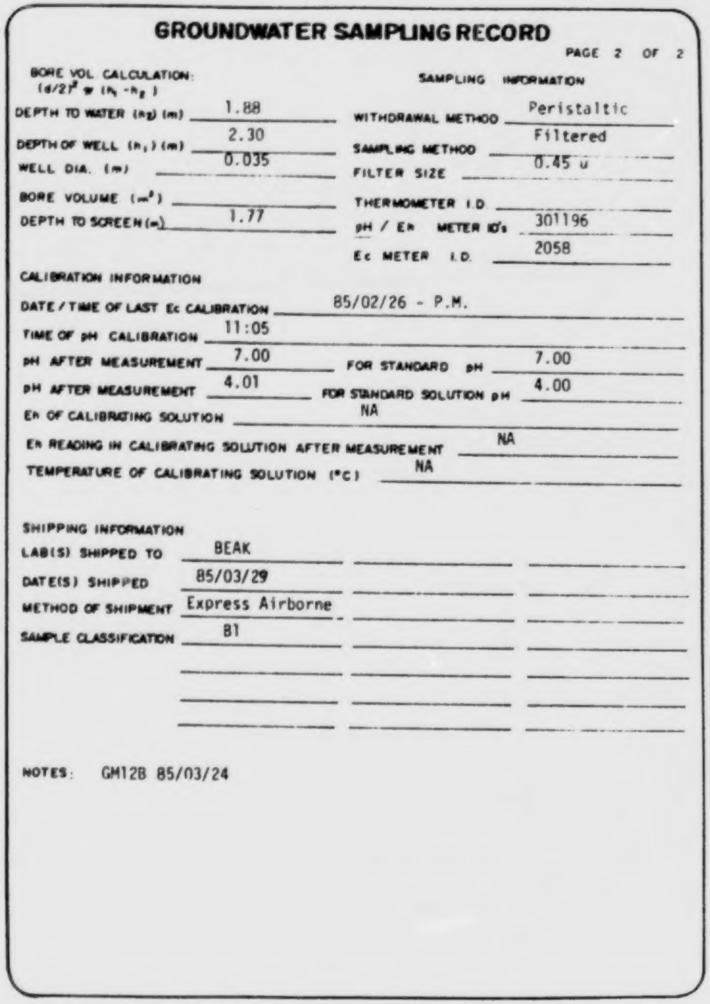
LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (L;tres)	(Bore Volume)	pH (S.U.)	E$_c$ (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED: Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
One litre			
150 ml	B1		
50 ml			
SPECIFY OTHERS :			

REMARKS: Used 1 filter. 1.6 N Lot #4240, 3% Salinity downhole

FIELD REP(S): B. Meays



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 1.88

DEPTH OF WELL (h_1) (m) 2.30

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 1.77

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 11:05

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO BEAK

DATE(S) SHIPPED 85/03/29

METHOD OF SHIPMENT Express Airborne

SAMPLE CLASSIFICATION B1

NOTES: GM12B 85/03/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM13A

SAMPLE ID B1, B2

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/03/23

SAMPLING TIME:

Start 10:00

Finish 10:45

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.08	
Ec (umhos/cm)	4950	4400
Eh (millivolts)		
TEMP. (°C)	8	3
ALKALINITY (mg/l CaCO₃)	273	@4.5
	282	@4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	E_c (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS.	500 ml	B1		
	230 ml		B2	1.5 ml

REMARKS: Used 1 filter. 1.6 N Lot #4240. 4% Salinity downhole

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 6.09

DEPTH OF WELL (h_1) (m) 7.31

WELL DIA. (m) 0.035

BORE VOLUME (m³)

DEPTH TO SCREEN (m) 6.86

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 10:05

pH AFTER MEASUREMENT 6.98 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.98 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION NA

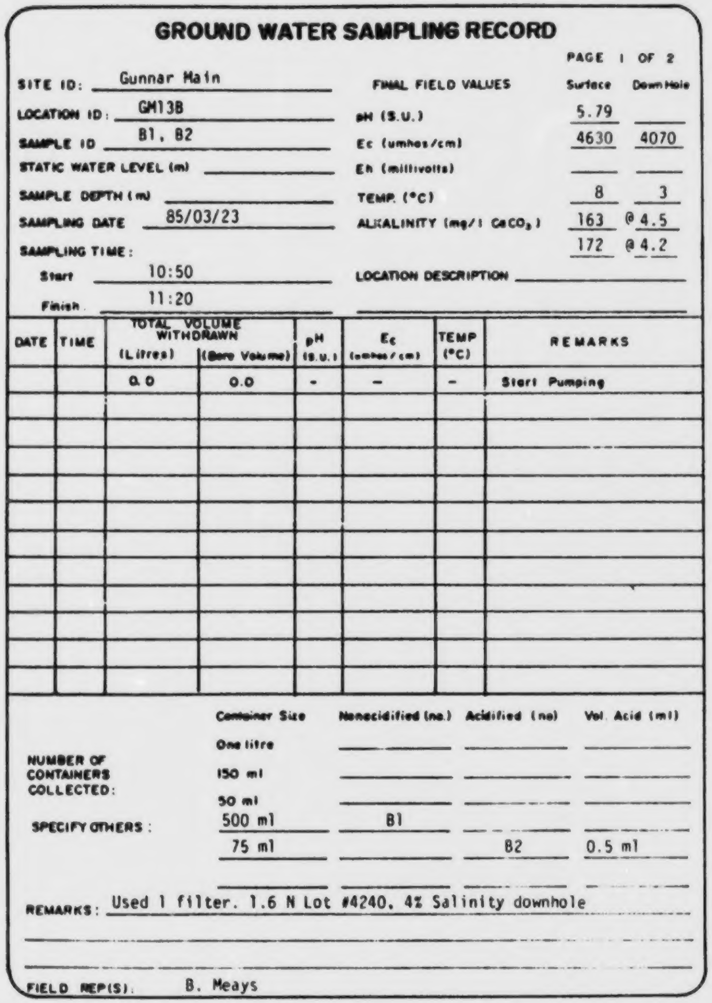
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK		
DATE(S) SHIPPED	85/03/29		
METHOD OF SHIPMENT	Express Airborne		
SAMPLE CLASSIFICATION	B1, B2		

NOTES: GM13A 85/03/23



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM13B

SAMPLE ID B1, B2

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/03/23

SAMPLING TIME:

Start 10:50

Finish 11:20

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	5.79	
Ec (umhos/cm)	4630	4070
Eh (millivolts)		
TEMP. (°C)	8	3
ALKALINITY (mg/l CaCO₃)	163	@ 4.5
	172	@ 4.2

LOCATION DESCRIPTION

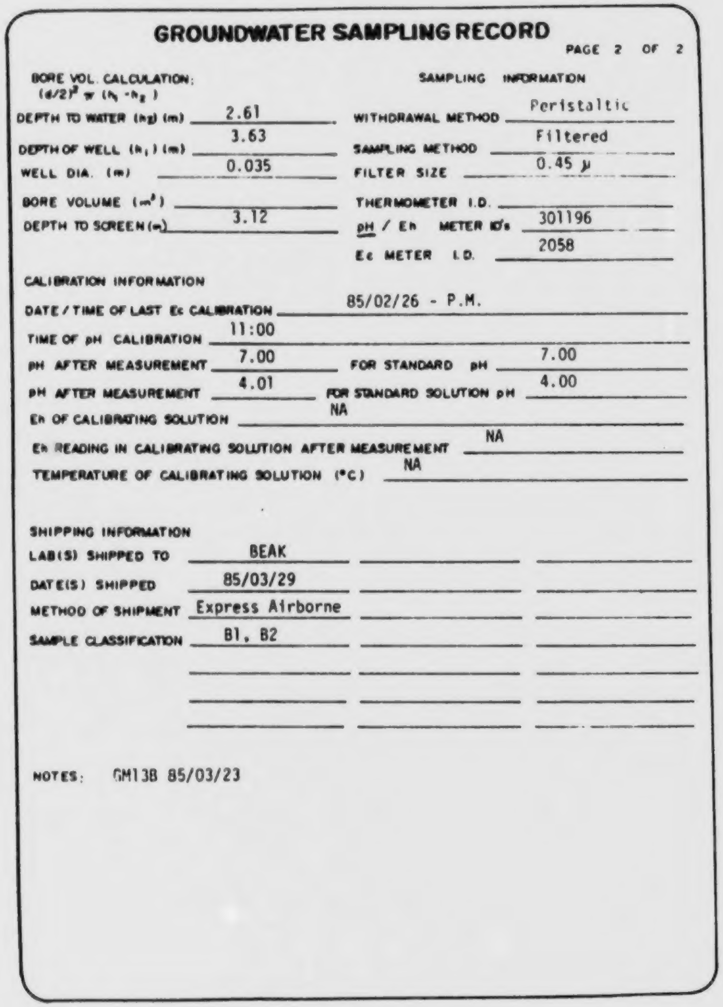
DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	75 ml		B2	0.5 ml

REMARKS: Used 1 filter. 1.6 N Lot #4240. 4% Salinity downhole

FIELD REP(S). B. Meays



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 2.61

DEPTH OF WELL (h_1) (m) 3.63

WELL DIA. (m) 0.035

BORE VOLUME (m³)

DEPTH TO SCREEN (m) 3.12

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 11:00

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

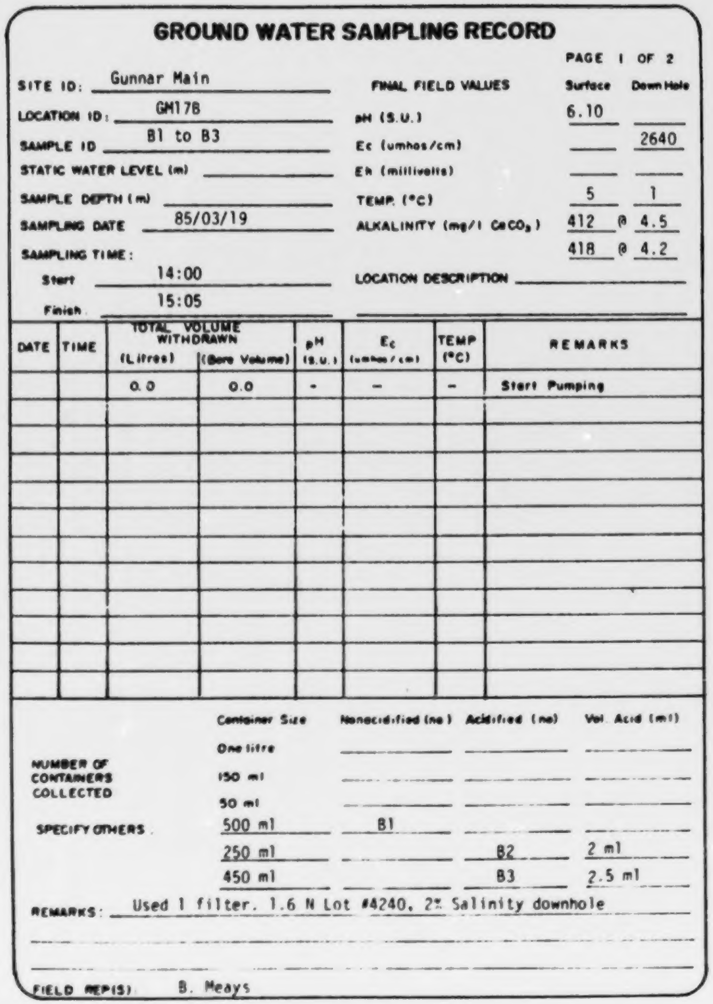
LAB(S) SHIPPED TO BEAK

DATE(S) SHIPPED 85/03/29

METHOD OF SHIPMENT Express Airborne

SAMPLE CLASSIFICATION B1, B2

NOTES: GM13B 85/03/23



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM178

SAMPLE ID B1 to B3

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/03/19

SAMPLING TIME:

Start 14:00

Finish 15:05

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.10	
Ec (umhos/cm)		2640
Eh (millivolts)		
TEMP. (°C)	5	1
ALKALINITY (mg/l CaCO$_3$)	412	@ 4.5
	418	@ 4.2

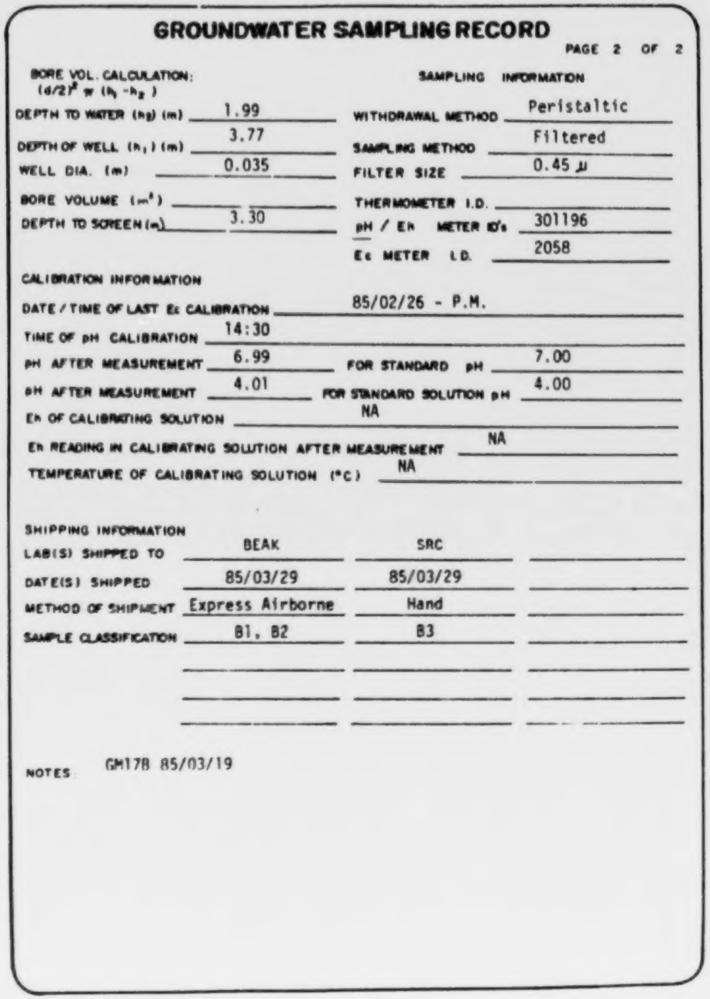
LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1		
	250 ml		B2	2 ml
	450 ml		B3	2.5 ml

REMARKS: Used 1 filter. 1.6 N Lot #4240. 2% Salinity downhole

FIELD REP(S) B. Meays



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 1.99

DEPTH OF WELL (h_1) (m) 3.77

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 3.30

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 14:30

pH AFTER MEASUREMENT 6.99 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION			
LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/03/29	85/03/29	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3	

NOTES GM17B 85/03/19

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM17C

SAMPLE ID B1, B2

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/03/19

SAMPLING TIME:

Start 15:15

Finish 15:45

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.15	
Ec (umhos/cm)		2900
Eh (millivolts)		
TEMP. (°C)	6	1
ALKALINITY (mg/l CaCO$_3$)	557 @ 4.5	
	567 @ 4.2	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS.	250 ml		B2	2 ml
	150 ml	B1		

REMARKS: Used 1 filter. 1.6 N Lot #4240. 3% Salinity downhole

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 1.52

DEPTH OF WELL (h_1) (m) 2.28

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 1.80

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 15:20

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO BEAK

DATE(S) SHIPPED 85/03/29

METHOD OF SHIPMENT Express Airborne

SAMPLE CLASSIFICATION B1, B2

NOTES: GM17C 85/03/19

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM19B

SAMPLE ID B1 to B4

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/03/21

SAMPLING TIME:

Start 10:00

Finish 11:00

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.30	
Ec (umhos/cm)		3120
Eh (millivolts)		
TEMP. (°C)	8	1
ALKALINITY (mg/l CaCO$_3$)	519 @	4.5
	530 @	4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
	One litre		B3	3 ml HNO$_3$
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1		
	250 ml		B2	2 ml
	200		B4	1.5 ml

REMARKS: Used 1 filter. 1.6 N Lot #4240. 3% Salinity downhole

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 2.12

DEPTH OF WELL (h_1) (m) 4.48

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 3.70

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 10:30

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.99 FOR STANDARD SOLUTION pH 4.00

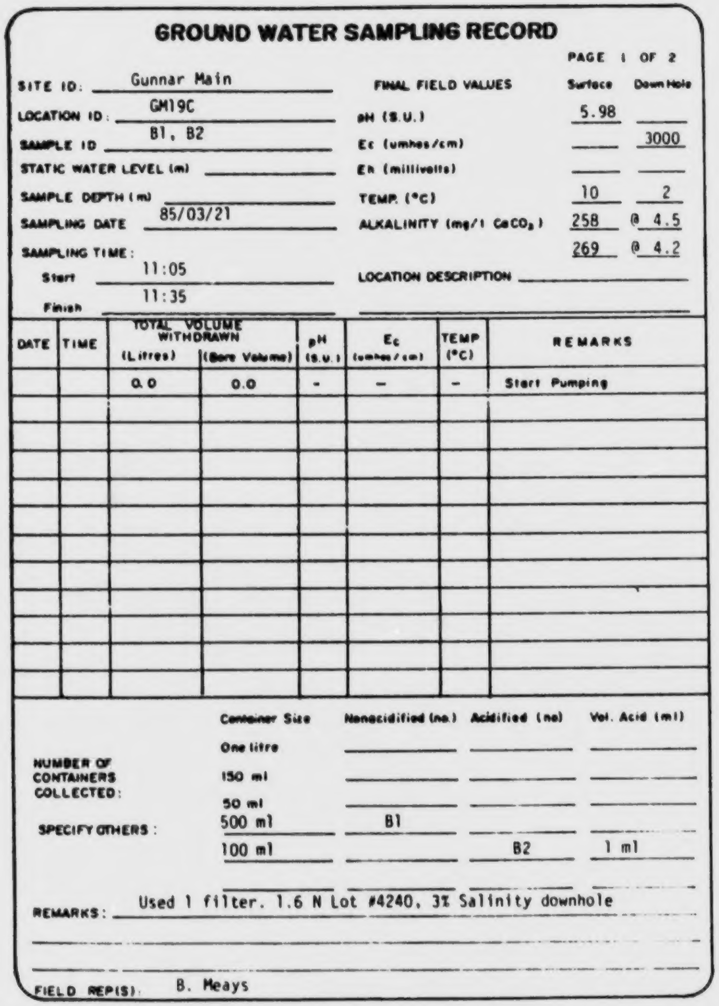
Eh OF CALIBRATING SOLUTION NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION			
LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/03/29	85/03/29	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES GM19B 85/03/21



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: GM19C
SAMPLE ID: B1, B2
STATIC WATER LEVEL (m):
SAMPLE DEPTH (m):
SAMPLING DATE: 85/03/21
SAMPLING TIME:
Start: 11:05
Finish: 11:35

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	5.98	
Ec (umhos/cm)		3000
Eh (millivolts)		
TEMP. (°C)	10	2
ALKALINITY (mg/l CaCO$_3$)	258	@ 4.5
	269	@ 4.2

LOCATION DESCRIPTION:

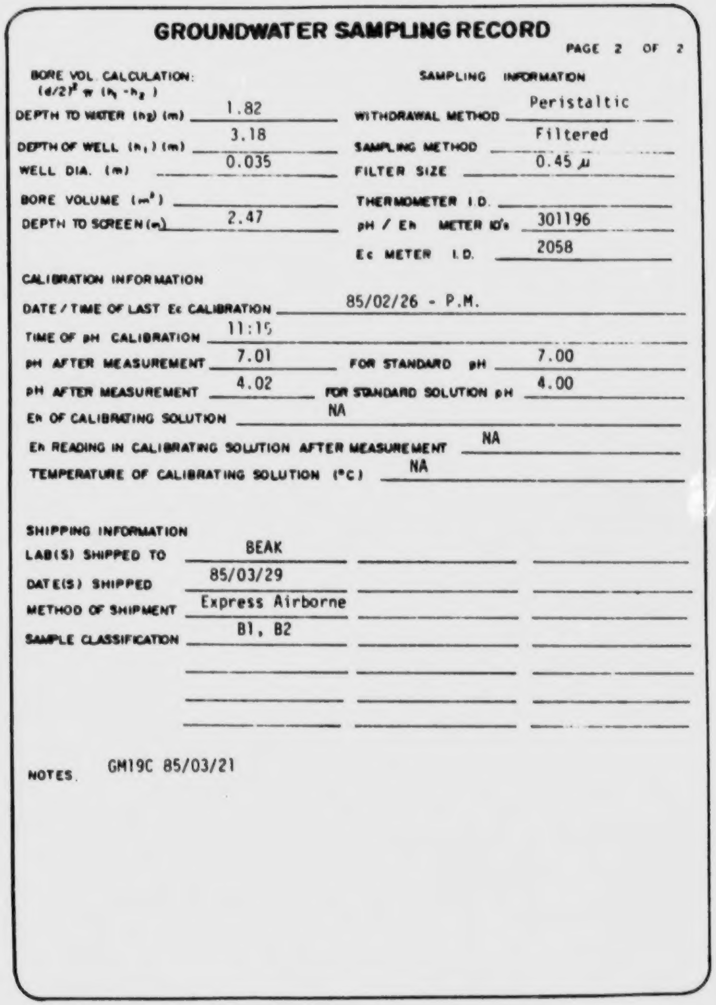
DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	–	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
One litre			
150 ml			
50 ml			
SPECIFY OTHERS: 500 ml	B1		
100 ml		B2	1 ml

REMARKS: Used 1 filter. 1.6 N Lot #4240. 3% Salinity downhole

FIELD REP(S): B. Meays



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
(d/2)^2 π (h$_1$ - h$_2$)
DEPTH TO WATER (h$_2$) (m): 1.82
DEPTH OF WELL (h$_1$) (m): 3.18
WELL DIA. (m): 0.035
BORE VOLUME (m^3):
DEPTH TO SCREEN (m): 2.47

SAMPLING INFORMATION
WITHDRAWAL METHOD: Peristaltic
SAMPLING METHOD: Filtered
FILTER SIZE: 0.45 μ
THERMOMETER I.D.:
pH / Eh METER ID's: 301196
Ec METER I.D.: 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION: 85/02/26 - P.M.
TIME OF pH CALIBRATION: 11:15
pH AFTER MEASUREMENT: 7.01 FOR STANDARD pH: 7.00
pH AFTER MEASUREMENT: 4.02 FOR STANDARD SOLUTION pH: 4.00
Eh OF CALIBRATING SOLUTION: NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT: NA
TEMPERATURE OF CALIBRATING SOLUTION (°C): NA

SHIPPING INFORMATION
LAB(S) SHIPPED TO: BEAK
DATE(S) SHIPPED: 85/03/29
METHOD OF SHIPMENT: Express Airborne
SAMPLE CLASSIFICATION: B1, B2

NOTES: GM19C 85/03/21

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Langley Bay
LOCATION ID: N5A
SAMPLE ID: B1, B2, B3
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE: 85/03/09
SAMPLING TIME:
Start: 09:30
Finish: 12:00

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.25	
Ec (umhos/cm)	580	
Eh (millivolts)		
TEMP. (°C)	4	
ALKALINITY (mg/l CaCO$_3$)	202	@ 4.5
	207	@ 4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
One litre			
150 ml			
50 ml			

SPECIFY OTHERS

Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
250 ml		B1	2 ml
500 ml		B2	2.5 m.
500 ml	B3		

REMARKS: Used 1 filter. 1.6 N Lot #4240, 0‰ Salinity

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m): 10.20
DEPTH OF WELL (h_1) (m): 12.18
WELL DIA. (m): 0.035
BORE VOLUME (m^3):
DEPTH TO SCREEN (m): 11.67

SAMPLING INFORMATION

WITHDRAWAL METHOD: Bailed
SAMPLING METHOD: Filtered
FILTER SIZE: 0.45 μ
THERMOMETER I.D.:
pH / Eh METER ID's: 301196
Ec METER I.D.: 2058

CALIBRATION INFORMATION

DATE/TIME OF LAST Ec CALIBRATION: 85/02/26 - P.M.
TIME OF pH CALIBRATION: 11:00
pH AFTER MEASUREMENT: 7.00 FOR STANDARD pH: 7.00
pH AFTER MEASUREMENT: 10.05 FOR STANDARD SOLUTION pH: 10.00
Eh OF CALIBRATING SOLUTION: NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT: NA
TEMPERATURE OF CALIBRATING SOLUTION (°C): NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/03/25	85/03/25	
METHOD OF SHIPMENT	Express Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B3	B2	

NOTES: N5A 85/03/09

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Langley Bay
LOCATION ID: N5B
SAMPLE ID
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 85/03/09
SAMPLING TIME:
Start 12:30
Finish 13:30

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.26	
Ec (umhos/cm)		2200
Eh (millivolts)		
TEMP. (°C)	6	3
ALKALINITY (mg/l CaCO$_3$)	267	@ 4.5
	275	@ 4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS:				

REMARKS: 1.6 N Lot #4240, 2% Salinity downhole

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m) 3.57
DEPTH OF WELL (h_1) (m) 3.91
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 3.36

SAMPLING INFORMATION
WITHDRAWAL METHOD Peristaltic
SAMPLING METHOD NA
FILTER SIZE NA
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.
TIME OF pH CALIBRATION 13:00
pH AFTER MEASUREMENT 3.99 FOR STANDARD pH 4.00
pH AFTER MEASUREMENT 6.99 FOR STANDARD SOLUTION pH 7.00
Eh OF CALIBRATING SOLUTION NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA
TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION
LAB(S) SHIPPED TO
DATE(S) SHIPPED
METHOD OF SHIPMENT
SAMPLE CLASSIFICATION

NOTES: N5B 85/03/09

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Langley Bay
LOCATION ID: LB2B
SAMPLE ID B1
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 85/03/26
SAMPLING TIME:
Start 11:20
Finish. 11:50

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.31	
Ec (umhos/cm)	2400	1720
Eh (millivolts)		
TEMP. (°C)	14	2
ALKALINITY (mg/l CaCO₃)	269	@ 4.5
	278	@ 4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	150 ml		B1	1 ml

REMARKS Used 1 filter. 1.6 N Lot #4310. 1% Salinity downhole

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

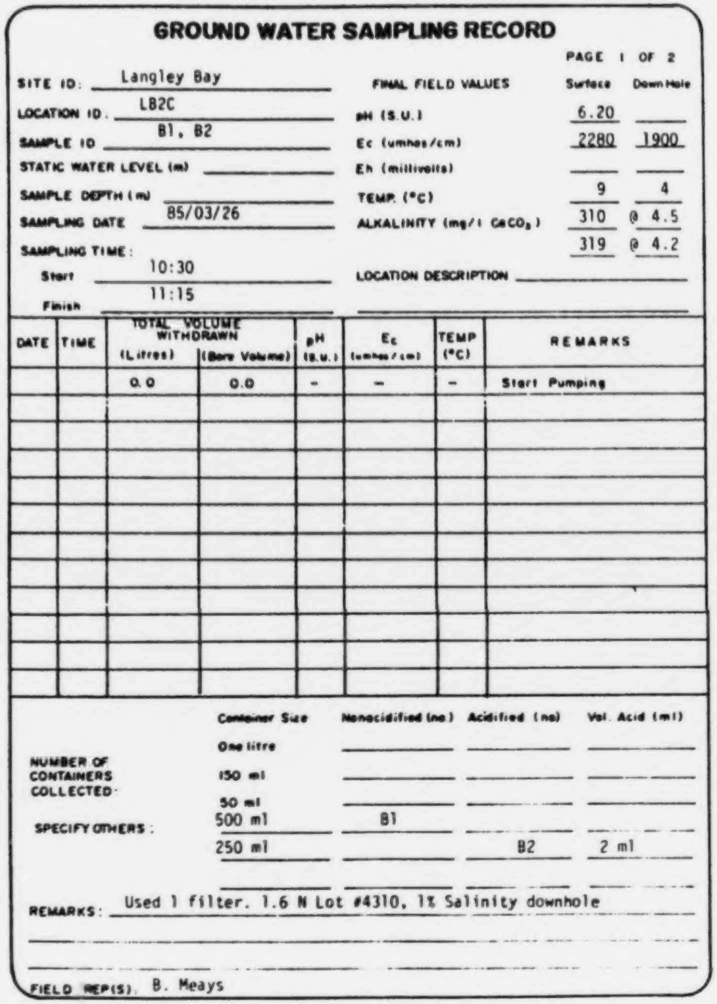
BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m) 3.56
DEPTH OF WELL (h_1) (m) 4.07
WELL DIA. (m) 0.035
BORE VOLUME (m³)
DEPTH TO SCREEN (m) 3.59

SAMPLING INFORMATION
WITHDRAWAL METHOD Peristaltic
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.
TIME OF pH CALIBRATION 11:25
pH AFTER MEASUREMENT 7.02 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA
TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION
LAB(S) SHIPPED TO BEAK
DATE(S) SHIPPED 85/03/29
METHOD OF SHIPMENT Express Airborne
SAMPLE CLASSIFICATION B1

NOTES LB2B 85/03/26



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Langley Bay
LOCATION ID. LB2C
SAMPLE ID B1, B2
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 85/03/26
SAMPLING TIME:
Start 10:30
Finish 11:15

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.20	
Ec (umhos/cm)	2280	1900
Eh (millivolts)		
TEMP. (°C)	9	4
ALKALINITY (mg/l $CaCO_3$)	310	@ 4.5
	319	@ 4.2

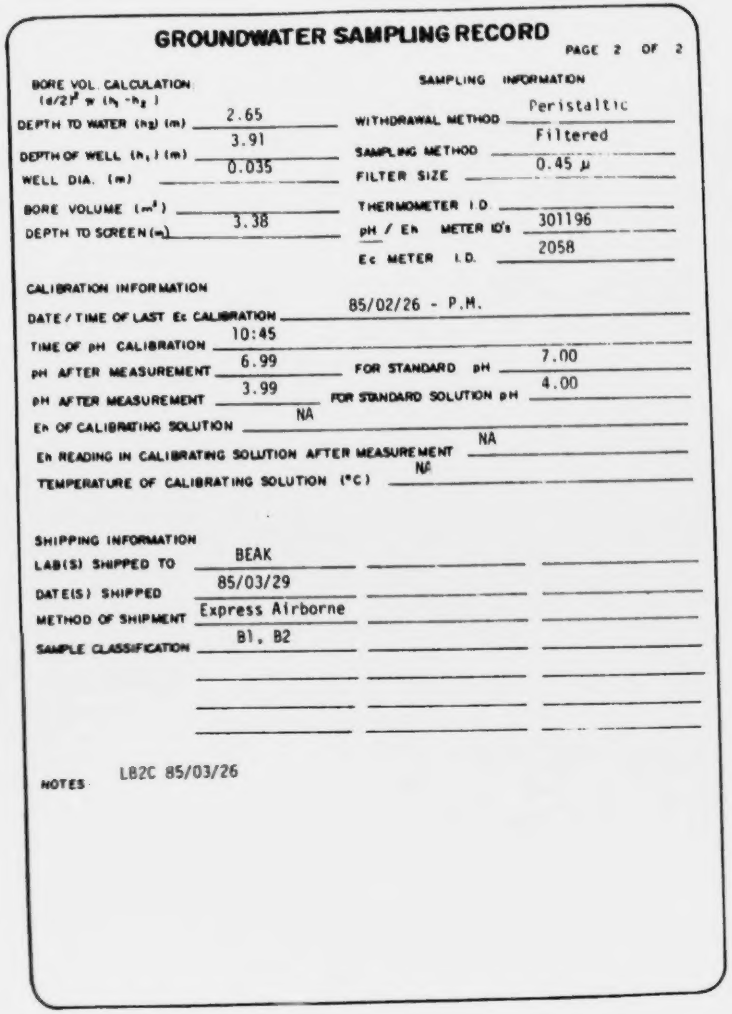
LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	250 ml		B2	2 ml

REMARKS: Used 1 filter. 1.6 N Lot #4310. 1% Salinity downhole

FIELD REP(S): B. Meays



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m) 2.65
DEPTH OF WELL (h_1) (m) 3.91
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 3.38

SAMPLING INFORMATION
WITHDRAWAL METHOD Peristaltic
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.
TIME OF pH CALIBRATION 10:45
pH AFTER MEASUREMENT 6.99 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 3.99 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA
TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION			
LAB(S) SHIPPED TO	BEAK		
DATE(S) SHIPPED	85/03/29		
METHOD OF SHIPMENT	Express Airborne		
SAMPLE CLASSIFICATION	B1, B2		

NOTES: LB2C 85/03/26

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Langley Bay
LOCATION ID: LB3C
SAMPLE ID B1
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 85/03/28
SAMPLING TIME:
Start 15:00
Finish 15:45

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.53	
Ec (umhos/cm)	2180	1780
Eh (millivolts)		
TEMP. (°C)	7	2
ALKALINITY (mg/l $CaCO_3$)	248	@ 4.5
	255	@ 4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS.	700 ml		B1	1 ml HNO_3

REMARKS: Used 1 filter. 1.6 N Lot #4310, 1' Salinity

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m) 3.71
DEPTH OF WELL (h_1) (m) 4.13
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 3.60

SAMPLING INFORMATION
WITHDRAWAL METHOD Peristaltic
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.
TIME OF pH CALIBRATION 15:15
pH AFTER MEASUREMENT 7.02 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION NA
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA
TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION			
LAB(S) SHIPPED TO	BEAK		
DATE(S) SHIPPED	85/04/02		
METHOD OF SHIPMENT	Express Airborne		
SAMPLE CLASSIFICATION	B1		

NOTES Trace of water and bottom at 1.84 m in LB3A

LB3C 85/03/28

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Langley Bay

LOCATION ID: LB7B

SAMPLE ID B1

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/03/28

SAMPLING TIME:

Start 11:40

Finish. 12:10

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.00	
Ec (umhos/cm)	2250	1520
Eh (millivolts)		
TEMP. (°C)	18	6
ALKALINITY (mg/l $CaCO_3$)	194	@ 4.5
	199	@ 4.2

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS.	125 ml		B1	1 ml

REMARKS: Used 1 filter. 1.6 N Lot #4310, 1% Salinity downhole

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) 4.12

DEPTH OF WELL (h_1) (m) 4.58

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 4.10

SAMPLING INFORMATION

WITHDRAWAL METHOD Peristaltic

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION 85/02/26 - P.M.

TIME OF pH CALIBRATION 11:50

pH AFTER MEASUREMENT 6.98 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.98 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION NA

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT NA

TEMPERATURE OF CALIBRATING SOLUTION (°C) NA

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK		
DATE(S) SHIPPED	85/04/02		
METHOD OF SHIPMENT	Express Airborne		
SAMPLE CLASSIFICATION	B1		

Piezometer No. LB7C

NOTES: Water level in LB7C - 2.40 m

Bottom at - 2.49 m

Not enough water in piezometer to sample

LB7B 85/03/28

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar

LOCATION ID GMIC (Field Blank)

SAMPLE ID B1, B2, B3

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/06

SAMPLING TIME

Start

Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)		
Ec (umhos/cm)		
Eh (millivolts)		
TEMP (°C)		
ALKALINITY (mg/l $CaCO_3$)		

LOCATION DESCRIPTION Field Blank

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
One litre		B2	2
150 ml			
50 ml			
SPECIFY OTHERS 500 ml	B1		
* 500 ml		B3	2

REMARKS Contains softened, demineralized, deionized water only.
* Filled to half.

FIELD REP(S) J. Brinkman, D. Lush

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m)

WELL DIA. (m)

BORE VOLUME (m^3)

DEPTH TO SCREEN (m)

SAMPLING INFORMATION

WITHDRAWAL METHOD Field Blank

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I.D.

pH / Eh METER ID's

Ec METER I.D.

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT FOR STANDARD pH

pH AFTER MEASUREMENT FOR STANDARD SOLUTION pH

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	06/26/85	06/26/85	
METHOD OF SHIPMENT	Hand Carried	Hand Carried	
SAMPLE CLASSIFICATION	B1, B2	B3	
	Anions	Total Uranium	
	Cations		

NOTES GMIC 85/06

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar - Main Pile

LOCATION ID NIC

SAMPLE ID B1 - B8

STATIC WATER LEVEL (m) 6.09

SAMPLE DEPTH (m)

SAMPLING DATE 6/23/35

SAMPLING TIME:

Start 1:50 pm

Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S U)	6.46	
Ec (umhos/cm)	4130	
Eh (millivolts)		
TEMP (°C)	12	
ALKALINITY (mg/l CaCO$_3$)	650 at pH 4.51 657 at pH 4.22	

LOCATION DESCRIPTION South east, Main Pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S U)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
	One litre		4	3
	150 ml			
	50 ml			
SPECIFY OTHERS.	500 ml	2		
	250 ml		2	2

REMARKS: 6 one liter bottles collected then combined into one container for split

FIELD REP(S) J. Brinkman, B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 10.18

WELL DIA (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 9.67

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I D

pH / Eh METER ID's 301196

Ec METER I D 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 7.01 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	Moneco
DATE(S) SHIPPED	6/26/85	6/26/85	6/26/85
METHOD OF SHIPMENT	Hand carried	Hand carried	Courier
SAMPLE CLASSIFICATION	B1, B3	B2, B4, B5, B6	B7, B8
	Anions	Anions, Cations	Total Uranium
	Cations	Total Uranium	Ra - 226
		Ra - 226, Pb-210	Pb - 210

NOTES NIC 85/06/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar
LOCATION ID: NIE
SAMPLE ID: B1, B2, B3
STATIC WATER LEVEL (m): 6.04
SAMPLE DEPTH (m):
SAMPLING DATE: 6/23/85
SAMPLING TIME:
Start
Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.03	
Ec (umhos/cm)	2490	
Eh (millivolts)		
TEMP (°C)	15	
ALKALINITY (mg/l $CaCO_3$)	134 at	pH 4.45
	137 at	pH 4.19

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Aci. (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		1	2
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml		1	2
	500 ml	1		

REMARKS

FIELD REP(S): J. Brinkman, B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m):
DEPTH OF WELL (h_1) (m): 8.15
WELL DIA. (m): 0.035
BORE VOLUME (m^3):
DEPTH TO SCREEN (m): 7.79

SAMPLING INFORMATION
WITHDRAWAL METHOD: Bailer
SAMPLING METHOD: Filtered
FILTER SIZE: 0.45 u
THERMOMETER I.D.:
pH / Eh METER ID's: 301196
Ec METER I.D.: 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION:
TIME OF pH CALIBRATION:
pH AFTER MEASUREMENT 6.96 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION:
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT:
TEMPERATURE OF CALIBRATING SOLUTION (°C):

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	6/26/85	6/26/85	
METHOD OF SHIPMENT	Hand carried	Hand carried	
SAMPLE CLASSIFICATION	B1, B2	B3	
	Anions	Total Uranium	
	Cations		

NOTES: NIE 85/06/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID. Gunnar
LOCATION ID N3A
SAMPLE ID B1, B2, B3
STATIC WATER LEVEL (m) 0.84
SAMPLE DEPTH (m)
SAMPLING DATE 6/23 to 6/24/85
SAMPLING TIME:
Start
Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	5.47	
Ec (umhos/cm)	5100	
Eh (millivolts)		
TEMP. (°C)	12	
ALKALINITY (mg/l $CaCO_3$)	146 at	pH 4.42
	153 at	pH 4.24

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	–	Start Pumping

NUMBER OF CONTAINERS COLLECTED:	Container Size	Nonacidified (no.)	Acidified (no.)	Vol. Acid (ml)
	One litre *		1	2
	150 ml			
	50 ml			
SPECIFY OTHERS.	500 ml	1		
	250 ml		1	2

REMARKS: Collected on 6/23, processed on 6/24/85
* about half full

FIELD REP(S) J. Brinkman, B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m) 4.17
WELL DIA (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 2.91

SAMPLING INFORMATION
WITHDRAWAL METHOD Bailer
SAMPLING METHOD Filtered
FILTER SIZE 0.45 μ
THERMOMETER I.D
pH / Eh METER ID's 301196
Ec METER I.D 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION
pH AFTER MEASUREMENT 4.05 FOR STANDARD pH 4.00
pH AFTER MEASUREMENT 7.03 FOR STANDARD SOLUTION pH 7.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	6/26/85	6/26/85	
METHOD OF SHIPMENT	Hand carried	Hand carried	
SAMPLE CLASSIFICATION	B1, B2	B3	
	Anions	Total Uranium	
	Cations		

NOTES: N3A 85/06/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID. Gunnar

LOCATION ID N3D

SAMPLE ID B1, B2, B3

STATIC WATER LEVEL (m) 0.81

SAMPLE DEPTH (m)

SAMPLING DATE 6/23 - 6/24/85

SAMPLING TIME:

Start

Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	5.93	
Ec (umhos/cm)	5800	
Eh (millivolts)		
TEMP (°C)	12	
ALKALINITY (mg/l CaCO$_3$)	403 at pH 4.46	
	411 at pH 4.18	

LOCATION DESCRIPTION North end of main pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	1	1	2
	250 ml		1	2

REMARKS Sampled on 6/23 and processed on 6/24/85

All bottles filled partially due to small sample volume.

FIELD REP(S) J. Brinkman, B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 2.17

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 1.01

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 7.01 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.02 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	6/26/85	6/26/85	
METHOD OF SHIPMENT	Hand carried	Hand carried	
SAMPLE CLASSIFICATION	B1, B2	B3	
	Anions	Total uranium	
	Cations		

NOTES N3D 85/06/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar - Central Pile

LOCATION ID N4D

SAMPLE ID B1, B2

STATIC WATER LEVEL (m) 1.58 from TOC

SAMPLE DEPTH (m)

SAMPLING DATE 6/22/85

SAMPLING TIME:

Start 11:28 am

Finish 3:00 pm

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	3.52	
Ec (umhos/cm)	19500	
Eh (millivolts)		
TEMP. (°C)	19	
ALKALINITY (mg/l $CaCO_3$)	0	

LOCATION DESCRIPTION Center of Gunnar Central

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS:	250 ml		B2	2
	500 ml	B1		

REMARKS: Collected 0.75 l in 2 parts at 11:30 am and at 3:00 pm. High sediment sample

FIELD REP(S) J. Brinkman, B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 2.17

WELL DIA (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 1.28

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I.D

pH / Eh METER ID's 301196

Ec METER I.D 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 2.01 FOR STANDARD pH 2.00

pH AFTER MEASUREMENT 3.98 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO Beak

DATE(S) SHIPPED 6/26/85

METHOD OF SHIPMENT Hand carried

SAMPLE CLASSIFICATION B1, B2

Anions

Cations

NOTES: N4D 85/06/22

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar - Langley Bay

LOCATION ID N5A

SAMPLE ID B1-B8

STATIC WATER LEVEL (m) 1.91 from TOC

SAMPLE DEPTH (m)

SAMPLING DATE 6/22/85

SAMPLING TIME.

Start 12:32 pm

Finish 2:30 pm

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.47	
Ec (umhos/cm)	510	
Eh (millivolts)		
TEMP (°C)	18	
ALKALINITY (mg/l $CaCO_3$)	200 at pH 4.50 203 at pH 4.20	

LOCATION DESCRIPTION Center of Langley Pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		B5, B6, B7, B8	3
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1, B2		
	250 ml		B3, B4	2

REMARKS Collected 6 liter containers, transported and combined into one split container for duplicate sample

FIELD REP(S) J. Brinkman, B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

		SAMPLING INFORMATION	
DEPTH TO WATER (h_2) (m)		WITHDRAWAL METHOD	Bailer
DEPTH OF WELL (h_1) (m)	12.18	SAMPLING METHOD	Filtered
WELL DIA. (m)	0.035	FILTER SIZE	0.45 u
BORE VOLUME (m^3)		THERMOMETER I.D.	
DEPTH TO SCREEN (m)	11.67	pH / Eh METER ID's	301196
		Ec METER I.D.	2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 6:25

pH AFTER MEASUREMENT 6.96 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 9.98 FOR STANDARD SOLUTION pH 10.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	Moneco
DATE(S) SHIPPED	6/26/85	6/26/85	6/26/85
METHOD OF SHIPMENT	Hand carried	Hand carried	Courier
SAMPLE CLASSIFICATION	B1, B3 Anions and Cations	B2, B4, B5, B7 Anions, Cations Ra-226, Total Uranium, Pb - 210	B6, B8 Ra - 226, Total Uranium, Pb - 210

NOTES For N5A 85/06/22

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID. Gunnar - Langley Bay

LOCATION ID N5B

SAMPLE ID B1, B2, B3

STATIC WATER LEVEL (m) 1.41 from TOC

SAMPLE DEPTH (m)

SAMPLING DATE 6/22/85

SAMPLING TIME:

Start 12:36 pm

Finish 2:28 pm

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.19	
Ec (umhos/cm)	3170	
Eh (millivolts)		
TEMP. (°C)	20	
ALKALINITY (mg/l $CaCO_3$)	280 at pH 4.52 286 at pH 4.17	

LOCATION DESCRIPTION Center of Langley Bay Pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre		B3	4
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	250 ml		B2	3

REMARKS: Allowed 2 hours of recovery then collected more sample, combined sample in field lab

FIELD REP(S): B. Meays, J. Brinkman

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 3.91

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 3.36

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 6.96 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.02 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

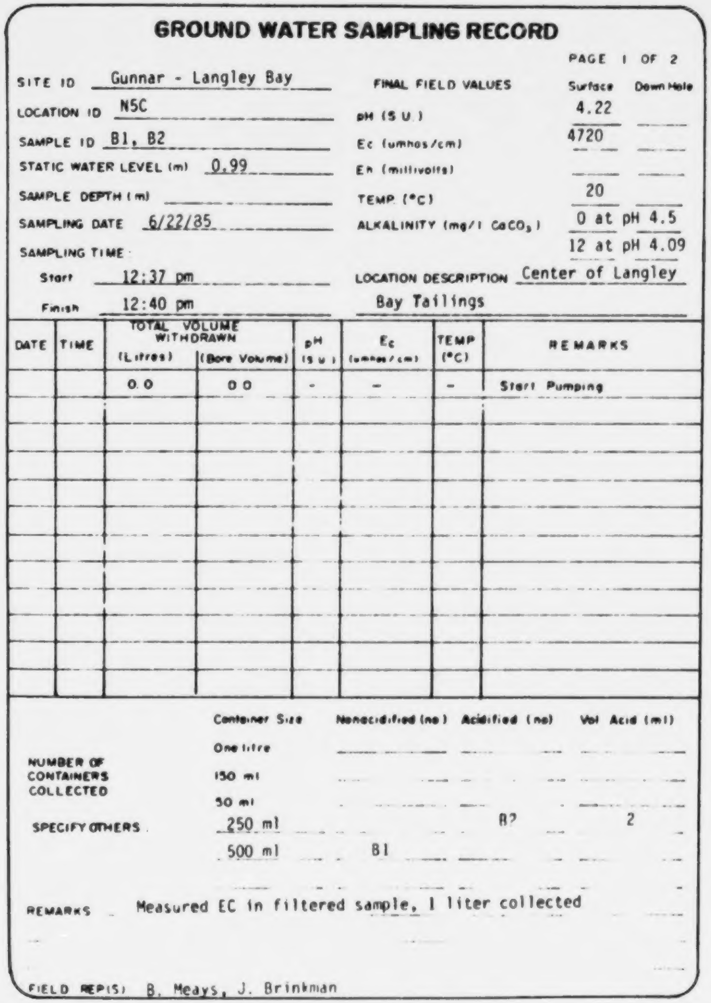
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	6/26/85	6/26/85	
METHOD OF SHIPMENT	Hand carried	Hand carried	
SAMPLE CLASSIFICATION	B1, B2	B3	
	Cations	Total Uranium	
	Anions	Ra - 226	
		Pb - 210	

NOTES: N5B 85/06/22



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID	Gunnar - Langley Bay	FINAL FIELD VALUES	Surface	Down Hole
LOCATION ID	N5C	pH (S.U.)	4.22	
SAMPLE ID	B1, B2	Ec (umhos/cm)	4720	
STATIC WATER LEVEL (m)	0.99	Eh (millivolts)		
SAMPLE DEPTH (m)		TEMP (°C)	20	
SAMPLING DATE	6/22/85	ALKALINITY (mg/l $CaCO_3$)	0 at pH 4.5 12 at pH 4.09	

SAMPLING TIME:
Start 12:37 pm
Finish 12:40 pm

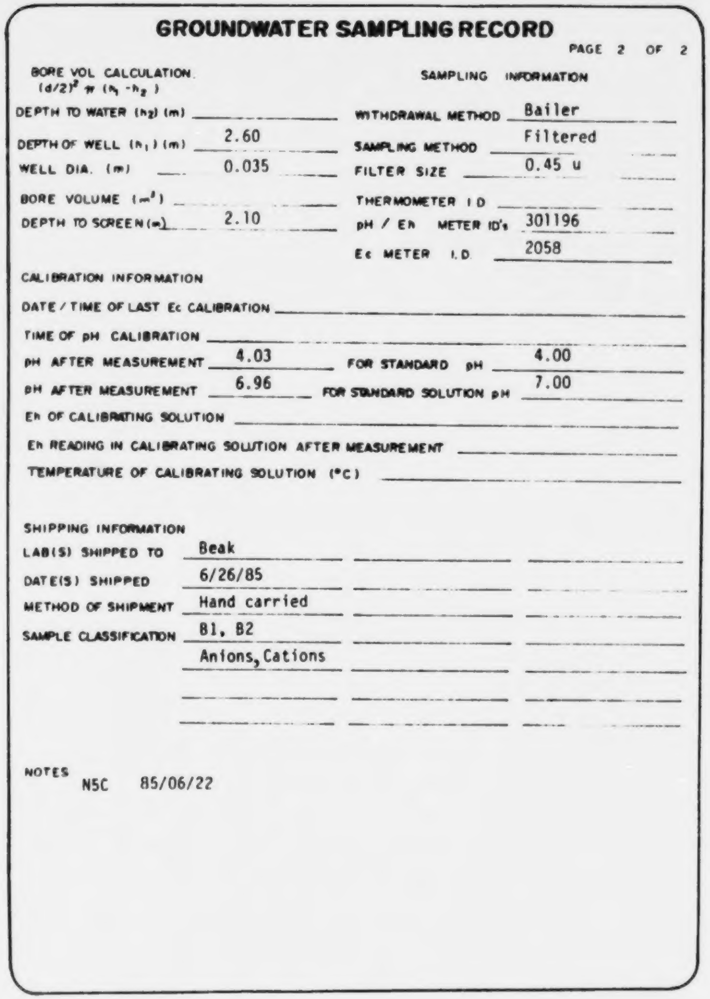
LOCATION DESCRIPTION Center of Langley Bay Tailings

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED	Container Size	Nonacidified (no.)	Acidified (no.)	Vol. Acid (ml)
	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml		B2	2
	500 ml	B1		

REMARKS Measured EC in filtered sample, 1 liter collected

FIELD REP(S) B. Meays, J. Brinkman



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION. $(d/2)^2 \pi (h_1 - h_2)$		SAMPLING INFORMATION	
DEPTH TO WATER (h_2) (m)		WITHDRAWAL METHOD	Bailer
DEPTH OF WELL (h_1) (m)	2.60	SAMPLING METHOD	Filtered
WELL DIA. (m)	0.035	FILTER SIZE	0.45 u
BORE VOLUME (m^3)		THERMOMETER I.D.	
DEPTH TO SCREEN (m)	2.10	pH / Eh METER ID's	301196
		Ec METER I.D.	2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 4.03 FOR STANDARD pH 4.00

pH AFTER MEASUREMENT 6.96 FOR STANDARD SOLUTION pH 7.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak		
DATE(S) SHIPPED	6/26/85		
METHOD OF SHIPMENT	Hand carried		
SAMPLE CLASSIFICATION	B1, B2		
	Anions, Cations		

NOTES N5C 85/06/22

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar

LOCATION ID N6B

SAMPLE ID B1, B2, B3, B4, B5

STATIC WATER LEVEL (m) 0.72

SAMPLE DEPTH (m)

SAMPLING DATE 85/06/23

SAMPLING TIME:

Start

Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.24	
Ec (umhos/cm)	3340	
Eh (millivolts)		
TEMP. (°C)	15	
ALKALINITY (mg/l $CaCO_3$)	233 at pH 4.48 239 at pH 4.20	

LOCATION DESCRIPTION Centre of Main Pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre		2	3
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	1		
	250 ml		1	2
	30 ml	1		

REMARKS: Collected 3 one liter container and combined in lab on barge

FIELD REP(S) B. Meays, J. Brinkman

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 5.76

WELL DIA (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 5.15

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 7.02 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.02 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	Waterloo	SRC
DATE(S) SHIPPED	6/26/85	6/26/85	6/26/85
METHOD OF SHIPMENT	Hand carried	Hand carried	Hand carried
SAMPLE CLASSIFICATION	B1, B2	B3	B4, B5
	Anions	Tritium	Total Uranium
	Cations		Ra - 226
			Pb - 210

NOTES: N6B 85/06/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar

LOCATION ID N6C

SAMPLE ID B1, B2, B3, B4, B5

STATIC WATER LEVEL (m) 0.62

SAMPLE DEPTH (m)

SAMPLING DATE 6/23/35

SAMPLING TIME:

Start 3:15 pm

Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	5.95	
Ec (umhos/cm)	4650	
Eh (millivolts)		
TEMP (°C)	14	
ALKALINITY (mg/l $CaCO_3$)	151 at pH 4.51 157 at pH 4.16	

LOCATION DESCRIPTION Center of Main Tailings Pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no.)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		2	2
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml		1	2
	500 ml	1		
	30 ml	1		

REMARKS

FIELD REP(S) J. Brinkman, B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 4.39

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 3.93

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	Waterloo	SRC
DATE(S) SHIPPED	6/26/85	6/26/85	6/26/85
METHOD OF SHIPMENT	Hand carried	Hand carried	Hand carried
SAMPLE CLASSIFICATION	B1, B2	B3	B4, B5
	Anions	Tritium	Total Uranium
	Cations		Ra - 226
			Pb - 210

NOTES N6C 85/06/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar

LOCATION ID N6D

SAMPLE ID B1, B2, B3, B4, B5

STATIC WATER LEVEL (m) 0.81

SAMPLE DEPTH (m)

SAMPLING DATE 6/23/85

SAMPLING TIME

Start

Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S U)	5.74	
Ec (umhos/cm)	4520	
Eh (millivolts)		
TEMP (°C)	15	
ALKALINITY (mg/l CaCO$_3$)	109 at pH 4.53	
	116 at pH 4.22	

LOCATION DESCRIPTION Center of Main Tailings Pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S U)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		2	2
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml		1	2
	500 ml	1		
	30 ml	1		

REMARKS

FIELD REP(S) J. Brinkman, B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 3.63

WELL DIA (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 2.97

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I D

pH / Eh METER ID's 301196

Ec METER I D 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 6.98 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.99 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	Waterloo	SRC
DATE(S) SHIPPED	6/26/85	6/26/85	6/26/85
METHOD OF SHIPMENT	Hand carried	Hand carried	Hand carried
SAMPLE CLASSIFICATION	B1, B2	B3	B4, B5
	Cations	Tritium	Total Uranium
	Anions		Ra - 226
			Pb - 210

NOTES N6D 85/06/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar

LOCATION ID N6E

SAMPLE ID B1, B2, B3, B4, B5

STATIC WATER LEVEL (m) 0.73

SAMPLE DEPTH (m)

SAMPLING DATE 6/23/85

SAMPLING TIME:

Start

Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.07	
Ec (umhos/cm)	3520	
Eh (millivolts)		
TEMP. (°C)	16	
ALKALINITY (mg/l CaCO$_3$)	194 at	pH 4.52
	201 at	pH 4.12

LOCATION DESCRIPTION Center of Main Pile

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)		pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		(Litres)	(Bore Volume)				
		0.0	0.0	-	–	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		2	2
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml		1	2
	500 ml	1		
	30 ml	1		

REMARKS

FIELD REP(S) J. Brinkman, B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 2.51

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 1.95

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 6.98 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.98 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	Waterloo	SRC
DATE(S) SHIPPED	6/26/85	6/26/85	6/26/85
METHOD OF SHIPMENT	Hand carried	Hand carried	Hand carried
SAMPLE CLASSIFICATION	B1, B2	B3	B4, B5
	Anions	Tritium	Total Uranium
	Cations		Ra - 226
			Pb -210

NOTES N6E 85/06/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar
LOCATION ID GM2B
SAMPLE ID
STATIC WATER LEVEL (m) 4.00
SAMPLE DEPTH (m)
SAMPLING DATE 6/23 6/24/85
SAMPLING TIME
Start
Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.38	
Ec (umhos/cm)	4000 (lab)	
Eh (millivolts)		
TEMP. (°C)	13	
ALKALINITY (mg/l CaCO$_3$)	841 at pH 4.54 850 at pH 4.20	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
One litre		1	2
150 ml			
50 ml			
SPECIFY OTHERS: 250 ml		1	2
500 ml	1		

REMARKS Sampled on 6/23, analysed on 6/24/85

FIELD REP(S) J. Brinkman, B. Meays, D. Lush

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m) 7.55
WELL DIA (m) 0.035
BORE VOLUME (m³)
DEPTH TO SCREEN (m) 6.97

SAMPLING INFORMATION
WITHDRAWAL METHOD Bailer
SAMPLING METHOD Filtered
FILTER SIZE 0.45 u
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION
pH AFTER MEASUREMENT 7.03 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	SRC - B3	Beak - B1	Beak - B2
DATE(S) SHIPPED	6/26/85	6/26/85	6/26/85
METHOD OF SHIPMENT	Hand carried	Hand carried	Hand carried
SAMPLE CLASSIFICATION	Uranium Only	Wet chemicals	Metals

NOTES GM2B 85/06/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar

LOCATION ID GM3B

SAMPLE ID B1, B2, B3

STATIC WATER LEVEL (m) 1.68

SAMPLE DEPTH (m)

SAMPLING DATE 6/23 to 6/24/85

SAMPLING TIME:

Start

Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.13	
Ec (umhos/cm)	4150	
Eh (millivolts)		
TEMP. (°C)	13	
ALKALINITY (mg/l CaCO$_3$)	257 at pH 4.45	
	263 at pH 4.23	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		1	2
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml		1	2
	500 ml	1		

REMARKS Sampled on 6/23, processed on 6/24

FIELD REP(S) J. Brinkman, B. Meays, D. Lush

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 10.41

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 9.90

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 4.04 FOR STANDARD pH 4.00

pH AFTER MEASUREMENT 7.01 FOR STANDARD SOLUTION pH 7.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	SRC - B3	Beak - B1	Beak - B2
DATE(S) SHIPPED	6/26/85	85/06/26	6/26/85
METHOD OF SHIPMENT	Hand carried	Hand carried	Hand carried
SAMPLE CLASSIFICATION	Total uranium	Wet chemicals	Metals

NOTES GM3B 85/06/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar

LOCATION ID GM3D

SAMPLE ID

STATIC WATER LEVEL (m) 1.43

SAMPLE DEPTH (m)

SAMPLING DATE 6/23/85

Analysed 6/24/85

SAMPLING TIME:

Start

Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.57	
Ec (umhos/cm)	3100	
Eh (millivolts)		
TEMP (°C)	14	
ALKALINITY (mg/l $CaCO_3$)	425 at pH 4.55	
	433 at pH 4.13	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		1	2
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml		1	1
	500 ml	1		

REMARKS

FIELD REP(S) J. Brinkman, B. Meays, D. Lush

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 5.13

WELL DIA (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 4.28

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 7.02 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.02 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO		Beak	SRC
DATE(S) SHIPPED		06/26/85	06/26/85
METHOD OF SHIPMENT		Hand Carried	Hand Carried
SAMPLE CLASSIFICATION		B1, B2	B3
		Anions	Total Uranium
		Cations	

NOTES G43D 85/06/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar
LOCATION ID GM3E
SAMPLE ID B1,B2, B3
STATIC WATER LEVEL (m) 1.28
SAMPLE DEPTH (m)
SAMPLING DATE 6/23/85
Analysed 6/24/85
SAMPLING TIME
Start
Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.6	
Ec (umhos/cm)	3100	
Eh (millivolts)		
TEMP. (°C)	13	
ALKALINITY (mg/l CaCO$_3$)	424	@ pH 4.47
	430	@ pH 4.24

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
One litre		1	2
150 ml			
50 ml			
SPECIFY OTHERS 250 ml		1	2
500 ml	1		

REMARKS

FIELD REP(S) J. Brinkman, D. Lush, B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m) 5.24
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 4.36

SAMPLING INFORMATION
WITHDRAWAL METHOD Bailer
SAMPLING METHOD Filtered
FILTER SIZE 0.45 u
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION
pH AFTER MEASUREMENT 7.02 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.02 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	SRC B1	Beak - B2	Beak - B3
DATE(S) SHIPPED	6/26/85	6/26/85	6/26/85
METHOD OF SHIPMENT	Hand carried	Hand carried	Hand carried
SAMPLE CLASSIFICATION	Uranium	Metals	Wet

NOTES GM3E 85/06/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID Gunnar

LOCATION ID GM22

SAMPLE ID B1, B2, B3, B4

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 6/23/85

SAMPLING TIME:

Start

Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.08	
Ec (umhos/cm)	1790	
Eh (millivolts)		
TEMP. (°C)	15	
ALKALINITY (mg/l CaCO$_3$)	73 at	pH 4.45
	77 at	pH 4.13

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS:	250 ml		1	2
	500 ml	1	2	2

REMARKS: Collected by Lush, processed by Brinkman and Meays

FIELD REP(S) D. Lush, B. Meays, J. Brinkman

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m)

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 0.8

SAMPLING INFORMATION

WITHDRAWAL METHOD Suction Hand Pump

SAMPLING METHOD Filtered

FILTER SIZE 0.45 u

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 7.02 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.02 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	6/26/85	6/26/85	
METHOD OF SHIPMENT	Hand carried	Hand carried	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	
	Anions	Total Uranium	
	Cations	Ra - 226	
		Pb - 210	

NOTES GM22 85/06/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar
LOCATION ID GM24
SAMPLE ID B1, B2, B3
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 6/22/85 - 6/23/85
SAMPLING TIME:
Start
Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.17	
Ec (umhos/cm)	4300	
Eh (millivolts)		
TEMP. (°C)	16	
ALKALINITY (mg/l CaCO$_3$)	135 at pH 4.46	
	140 at pH 4.16	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml		1	2
	500 ml	1	1	2

REMARKS Collect by Lush on 6/22 and 6/23/85
Processed by Meays and Brinkman on 6/23/85

FIELD REP(S) J. Brinkman, B. Meays, D. Lush

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m)
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 0.90

SAMPLING INFORMATION
WITHDRAWAL METHOD Suction Hand Pump
SAMPLING METHOD Filtered
FILTER SIZE 0.45 u
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION
pH AFTER MEASUREMENT 7.01 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.03 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	6/26/85	6/26/85	
METHOD OF SHIPMENT	Hand carried	Hand carried	
SAMPLE CLASSIFICATION	B1, B2	B3	
	Cations	Total Uranium	
	Anions		

NOTES GM24 85/06/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID. Gunnar - St. Mary's Channel

LOCATION ID SM1

SAMPLE ID B1, B2, B3

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 6/22/85

SAMPLING TIME:

Start 9:30 pm

Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.26	
Ec (umhos/cm)	58	
Eh (millivolts)		
TEMP. (°C)	10	
ALKALINITY (mg/l CaCO$_3$)	36 at pH 4.46 38 at pH 4.22	

LOCATION DESCRIPTION St. Mary's Channel Athabasca, outside barge

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0 0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
One litre			
150 ml			
50 ml			
SPECIFY OTHERS 500 ml	1		
500 ml		1	2
250 ml		1	2

REMARKS: Water that was used for rinse water for bottles and sample processing

FIELD REP(S) B. Meays, J. Brinkman

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m)

WELL DIA (m)

BORE VOLUME (m^3)

DEPTH TO SCREEN (m)

SAMPLING INFORMATION

WITHDRAWAL METHOD Collected in rinse par

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D

pH / Eh METER ID's 301196

Ec METER I.D 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION

pH AFTER MEASUREMENT 10.08 FOR STANDARD pH 10.0

pH AFTER MEASUREMENT 7.01 FOR STANDARD SOLUTION pH 7.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	SRC	
DATE(S) SHIPPED	6/26/85	6/26/85	
METHOD OF SHIPMENT	Hand carried	Hand carried	
SAMPLE CLASSIFICATION	B1, B2	B3	
	Anions	Total Uranium	
	Cations		

NOTES. SM1 85/06/22

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID. Gunnar - St. Mary's Channel
LOCATION ID SM2
SAMPLE ID B1, B2, B3, B4,
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 6/23/85
SAMPLING TIME:
Start 1:00 pm
Finish

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.67	
Ec (umhos/cm)	52	
Eh (millivolts)		
TEMP. (°C)	10	
ALKALINITY (mg/l CaCO$_3$)	32 at	pH 4.43
Lot # 4310 1.6 N	35 at	pH 4.17

LOCATION DESCRIPTION Shore of St. Mary's Channel, approx. 100 m W of barge

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS	250 ml		1	2
	500 ml	1	1	2
	30 ml	1		

REMARKS

FIELD REP(S) B. Meays, J. Brinkman

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$		SAMPLING INFORMATION	
DEPTH TO WATER (h_2) (m)		WITHDRAWAL METHOD	Pan
DEPTH OF WELL (h_1) (m)		SAMPLING METHOD	Filtered
WELL DIA. (m)		FILTER SIZE	0.45 u
BORE VOLUME (m^3)		THERMOMETER I.D.	
DEPTH TO SCREEN (m)		pH / Eh METER ID's	301196
		Ec METER I.D.	2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION
pH AFTER MEASUREMENT 7.02 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 10.00 FOR STANDARD SOLUTION pH 10.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	Beak	Waterloo	SRC
DATE(S) SHIPPED	6/26/85	6/26/85	6/26/85
METHOD OF SHIPMENT	Hand carried	Hand carried	Hand carried
SAMPLE CLASSIFICATION	B1, B2	B3	B4,
	Anions	Tritium	Total Uranium
	Cations		

NOTES SM2 85/06/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: NIC

SAMPLE ID B1 to B8

STATIC WATER LEVEL (m) 5.72

SAMPLE DEPTH (m)

SAMPLING DATE 85/08/24

SAMPLING TIME:

Start 8:25

Finish. 9:00

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.44	
Ec (umhos/cm)	3620	
Eh (millivolts)		
TEMP. (°C)	13	
ALKALINITY (mg/l CaCO$_3$)	678	@ 4.51
	690	@ 4.19

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)		pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		(Litres)	(Bore Volume)				
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

SPECIFY OTHERS.

Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
One litre		B5, B6, B7, B8	4
150 ml			
50 ml			
500 ml	B1, B2		
250 ml		B3, B4	1

REMARKS: Collected 6 litre bottles and combined in a tub and filtered.

FIELD REP(S). B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 10.18

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 9.67

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailed

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I.D.

pH / Eh METER I.D.'s 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 8:30

pH AFTER MEASUREMENT 7.01 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.02 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	Monenco
DATE(S) SHIPPED	85/09/27	85/09/27	85/09/27
METHOD OF SHIPMENT	Airborne	Hand	Airborne
SAMPLE CLASSIFICATION	B1, B3	B2, B4, B6, B8	B5, B7
	Anions and	Anions, Cations	Ra-226, Total
	Cations	Ra-226, Total	Uranium, Pb-210
		Uranium, Pb-210	

NOTES: Piezometer bailed out previous day.

NIC 85/08/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar

LOCATION ID: N2E

SAMPLE ID B1, B2, B3, B4

STATIC WATER LEVEL (m) 0.97

SAMPLE DEPTH (m)

SAMPLING DATE 85/08/24

SAMPLING TIME:

Start 3:20

Finish 3:40

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.47	
Ec (umhos/cm)	3220	
Eh (millivolts)		
TEMP. (°C)	17	
ALKALINITY (mg/l CaCO$_3$)	554 @	4.47
	563 @	4.21

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
One litre		B3, B4	3
150 ml			
50 ml			
SPECIFY OTHERS: 500 ml	B1		1
250 ml		B2	

REMARKS:

FIELD REP(S) D. Downing/B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 8.09

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 7.60

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 3:25

pH AFTER MEASUREMENT 7.01 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/09/27	85/09/27	
METHOD OF SHIPMENT	Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES: N2E 85/08/25

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar
LOCATION ID: N2G
SAMPLE ID B1, B2, B3, B4
STATIC WATER LEVEL (m) 1.08
SAMPLE DEPTH (m)
SAMPLING DATE 85/08/24
SAMPLING TIME:
Start 3:45
Finish. 4:07

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.51	
Ec (umhos/cm)	3220	
Eh (millivolts)		
TEMP. (°C)	18	
ALKALINITY (mg/l $CaCO_3$)	585	@ 4.40
	592	@ 4.13

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	–	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED.	One litre		B3, B4	3
	150 ml			
	50 ml			
SPECIFY OTHERS.	500 ml	B1		
	250 ml		B2	1

REMARKS:

FIELD REP(S) B. Meays/D. Downing

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

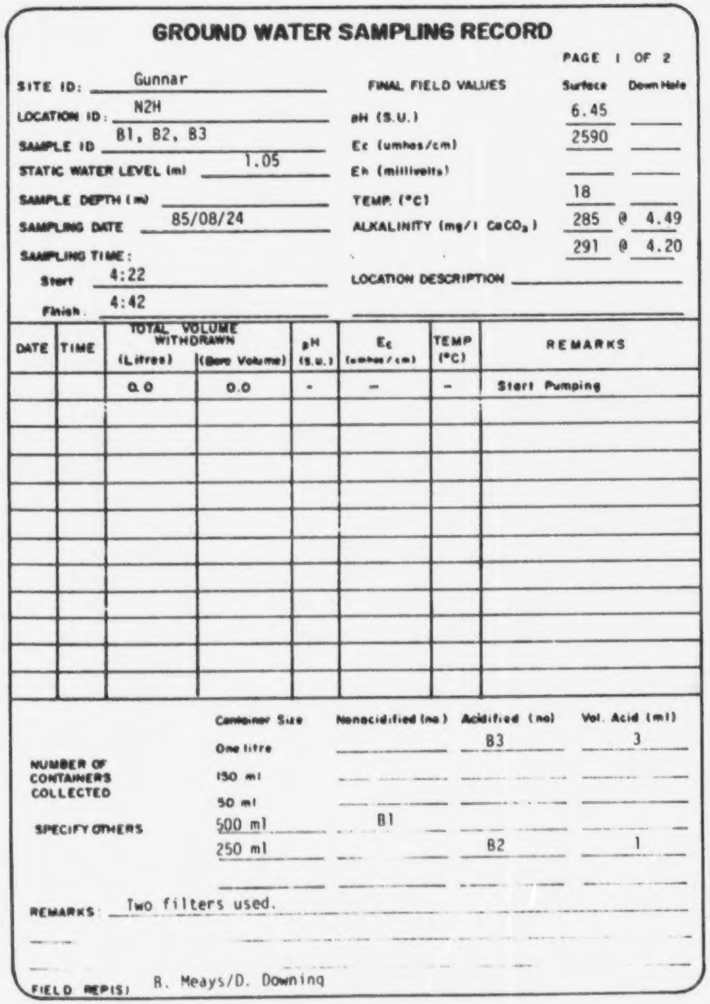
BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m) 5.95
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 5.39

SAMPLING INFORMATION
WITHDRAWAL METHOD Bailer
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION 3:25
pH AFTER MEASUREMENT 7.01 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION
LAB(S) SHIPPED TO
DATE(S) SHIPPED
METHOD OF SHIPMENT
SAMPLE CLASSIFICATION

NOTES: Piezometer bailed out previous day.
N2G 85/08/24



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar

LOCATION ID: N2H

SAMPLE ID B1, B2, B3

STATIC WATER LEVEL (m) 1.05

SAMPLE DEPTH (m) ______

SAMPLING DATE 85/08/24

SAMPLING TIME:

Start 4:22

Finish 4:42

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.45	
Ec (umhos/cm)	2590	
Eh (millivolts)		
TEMP. (°C)	18	
ALKALINITY (mg/l CaCO$_3$)	285 @	4.49
	291 @	4.20

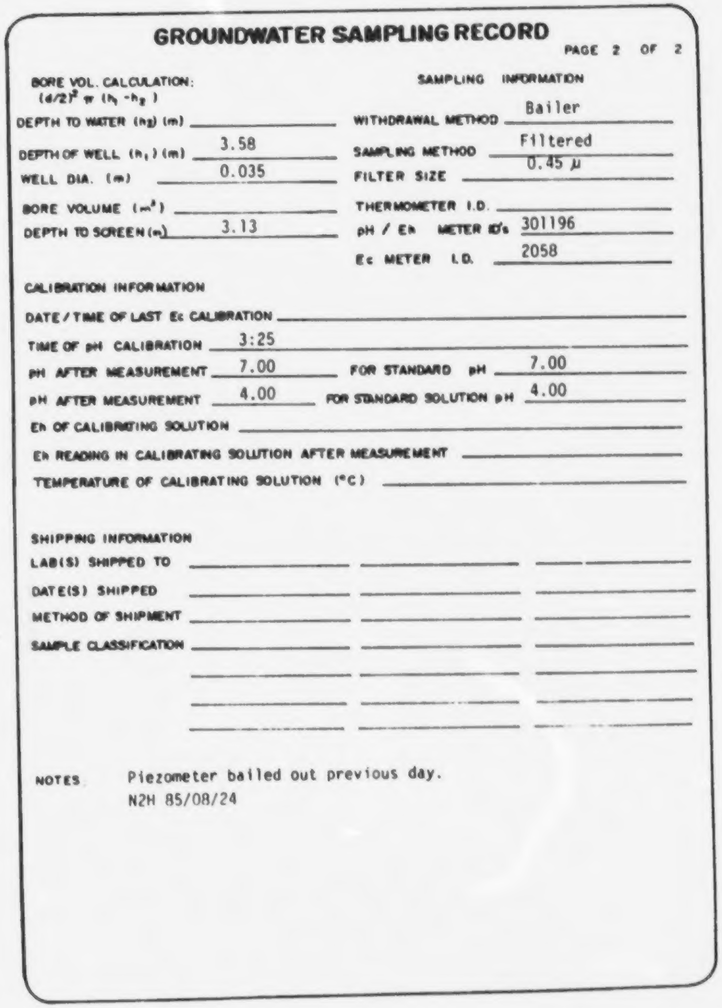
LOCATION DESCRIPTION ______

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	–	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		B3	3
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1		
	250 ml		B2	1

REMARKS: Two filters used.

FIELD REP(S) R. Meays/D. Downing



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m) ______

DEPTH OF WELL (h_1) (m) 3.58

WELL DIA. (m) 0.035

BORE VOLUME (m^3) ______

DEPTH TO SCREEN (m) 3.13

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I.D. ______

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION ______

TIME OF pH CALIBRATION 3:25

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION ______

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT ______

TEMPERATURE OF CALIBRATING SOLUTION (°C) ______

SHIPPING INFORMATION

LAB(S) SHIPPED TO ______

DATE(S) SHIPPED ______

METHOD OF SHIPMENT ______

SAMPLE CLASSIFICATION ______

NOTES Piezometer bailed out previous day.
N2H 85/08/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar

LOCATION ID: N3A

SAMPLE ID B1, B2, B3

STATIC WATER LEVEL (m) 1.08

SAMPLE DEPTH (m)

SAMPLING DATE 85/08/24

SAMPLING TIME:

Start 4:47

Finish 5:05

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	5.42	
Ec (umhos/cm)	5000	
Eh (millivolts)		
TEMP. (°C)	18	
ALKALINITY (mg/l CaCO$_3$)	120 @ 4.49	
	125 @ 4.24	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B3	2
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	250 ml		B2	1

REMARKS: Sample has slight odor. Used 2 filters. B3 - 1/2 litre.

FIELD REP(S) D. Downing/B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL CALCULATION:
($d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 4.17

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 2.91

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 3:25

pH AFTER MEASUREMENT 7.02 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

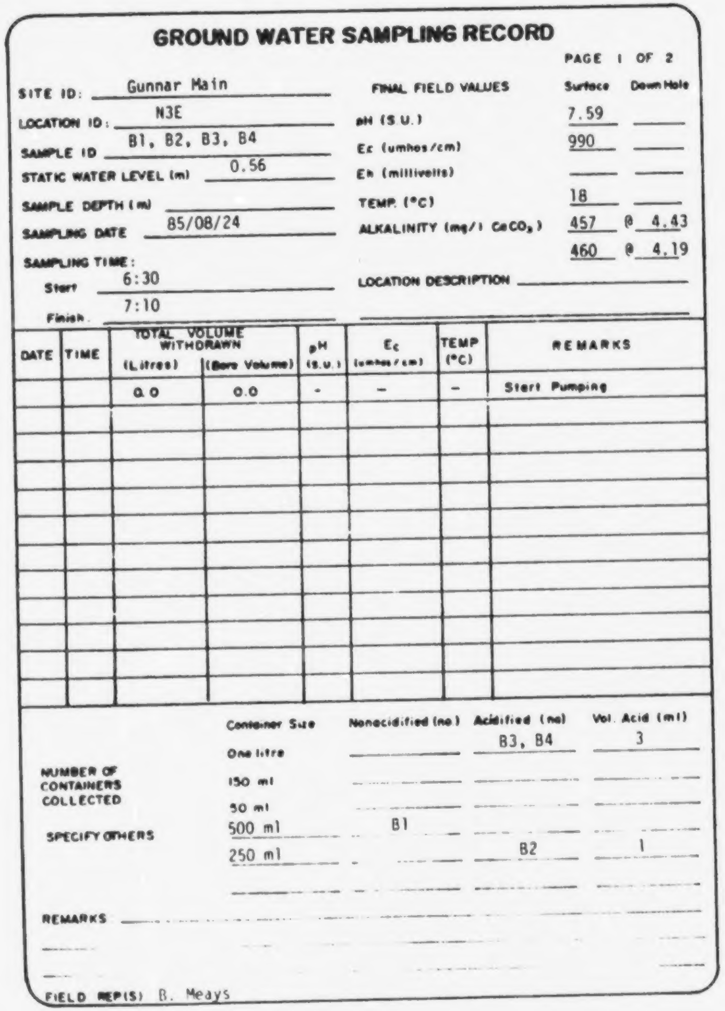
LAB(S) SHIPPED TO

DATE(S) SHIPPED

METHOD OF SHIPMENT

SAMPLE CLASSIFICATION

NOTES: N3A 85/08/24



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: N3E

SAMPLE ID B1, B2, B3, B4

STATIC WATER LEVEL (m) 0.56

SAMPLE DEPTH (m)

SAMPLING DATE 85/08/24

SAMPLING TIME:

Start 6:30

Finish 7:10

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.59	
Ec (umhos/cm)	990	
Eh (millivolts)		
TEMP. (°C)	18	
ALKALINITY (mg/l $CaCO_3$)	457	@ 4.43
	460	@ 4.19

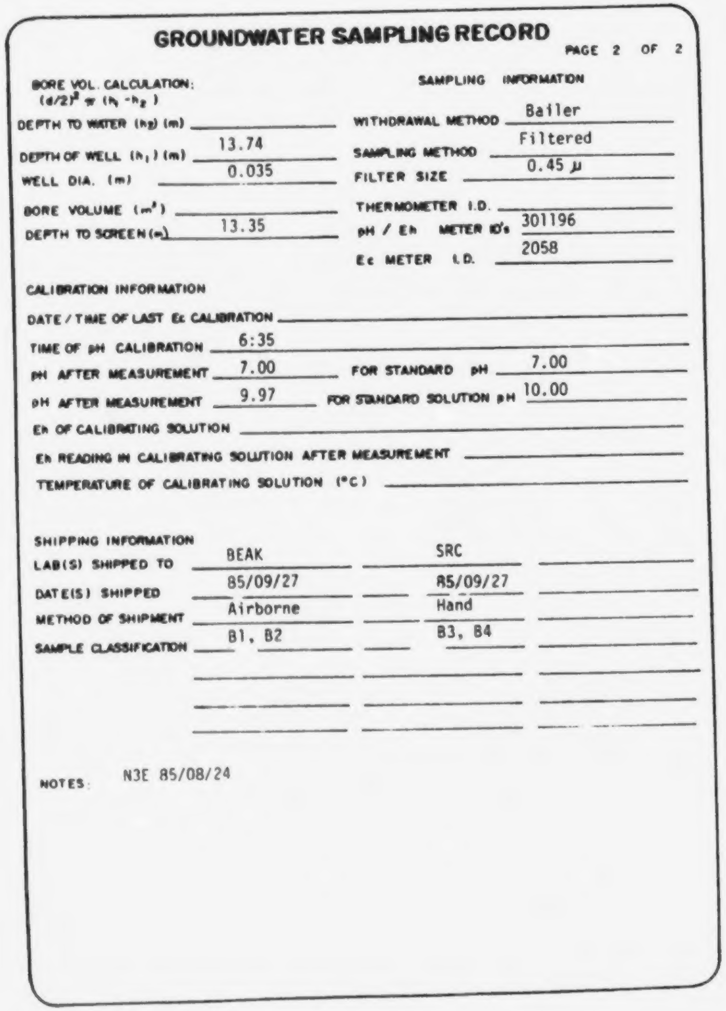
LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	–	Start Pumping

NUMBER OF CONTAINERS COLLECTED	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre		B3, B4	3
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1		
	250 ml		B2	1

REMARKS

FIELD REP(S) B. Meays



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 13.74

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 13.35

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 6:35

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 9.97 FOR STANDARD SOLUTION pH 10.00

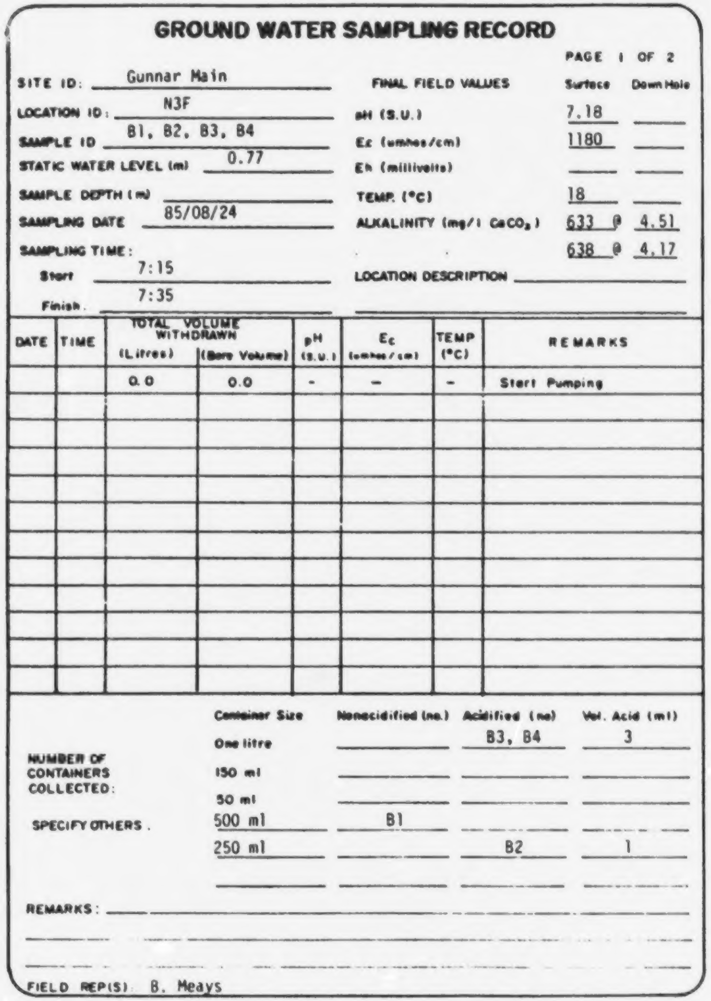
Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION			
LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/09/27	85/09/27	
METHOD OF SHIPMENT	Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES: N3E 85/08/24



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: N3F
SAMPLE ID B1, B2, B3, B4
STATIC WATER LEVEL (m) 0.77
SAMPLE DEPTH (m)
SAMPLING DATE 85/08/24
SAMPLING TIME:
Start 7:15
Finish. 7:35

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.18	
Ec (umhos/cm)	1180	
Eh (millivolts)		
TEMP. (°C)	18	
ALKALINITY (mg/l CaCO$_3$)	633 @	4.51
	638 @	4.17

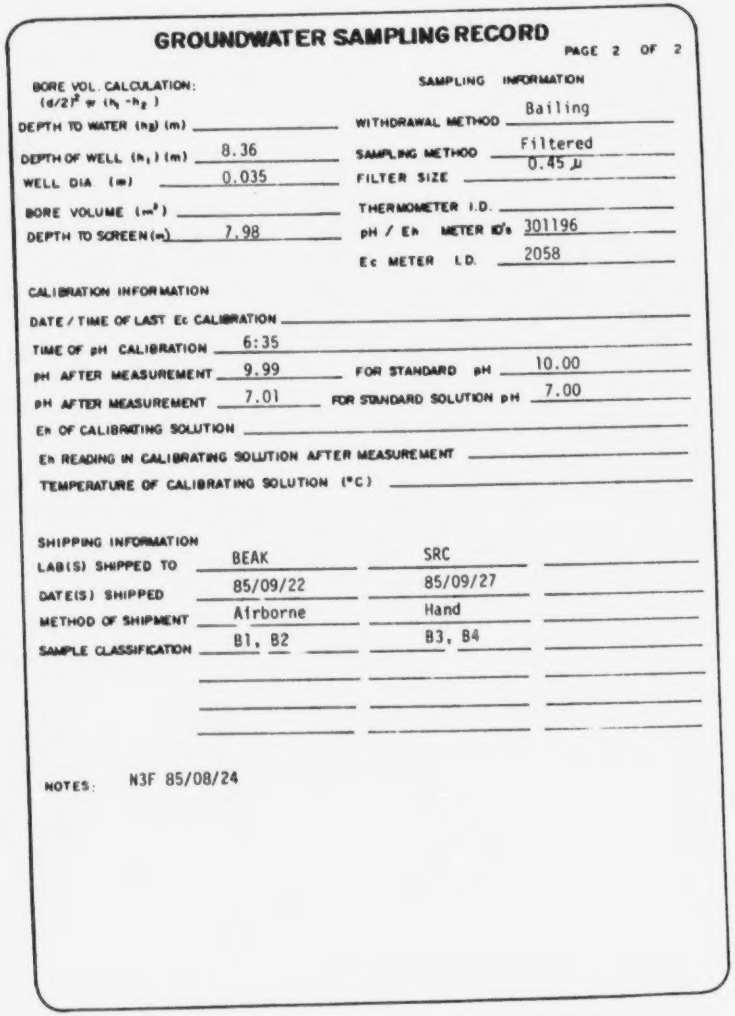
LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	(Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B3, B4	3
	150 ml			
	50 ml			
SPECIFY OTHERS.	500 ml	B1		
	250 ml		B2	1

REMARKS:

FIELD REP(S) B. Meays



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m) 8.36
WELL DIA (m) 0.035
BORE VOLUME (m³)
DEPTH TO SCREEN (m) 7.98

SAMPLING INFORMATION
WITHDRAWAL METHOD Bailing
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION 6:35
pH AFTER MEASUREMENT 9.99 FOR STANDARD pH 10.00
pH AFTER MEASUREMENT 7.01 FOR STANDARD SOLUTION pH 7.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION			
LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/09/22	85/09/27	
METHOD OF SHIPMENT	Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES: N3F 85/08/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Central
LOCATION ID: N4A
SAMPLE ID: B1, B2, B3, B4
STATIC WATER LEVEL (m): 1.18
SAMPLE DEPTH (m):
SAMPLING DATE: 85/08/23
SAMPLING TIME:
Start: 8:35
Finish: 9:10

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.09	
Ec (umhos/cm)	1480	
Eh (millivolts)		
TEMP. (°C)	18	
ALKALINITY (mg/l $CaCO_3$)	372	@ 4.52
	374	@ 4.12

LOCATION DESCRIPTION:

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		B3, B4	2
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1		
	250 ml		B2	1

REMARKS:

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m):
DEPTH OF WELL (h_1) (m): 5.92
WELL DIA. (m): 0.035
BORE VOLUME (m^3):
DEPTH TO SCREEN (m): 5.41

SAMPLING INFORMATION
WITHDRAWAL METHOD: Bailing
SAMPLING METHOD: Filtered
FILTER SIZE: 0.45 μ
THERMOMETER I.D.:
pH / Eh METER ID's: 301196
Ec METER I.D.: 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION:
TIME OF pH CALIBRATION: 8:45
pH AFTER MEASUREMENT: 7.01 FOR STANDARD pH: 7.00
pH AFTER MEASUREMENT: 9.98 FOR STANDARD SOLUTION pH: 10.00
Eh OF CALIBRATING SOLUTION:
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT:
TEMPERATURE OF CALIBRATING SOLUTION (°C):

SHIPPING INFORMATION			
LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/09/27	85/09/27	
METHOD OF SHIPMENT	Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES: N4A 85/08/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Central

LOCATION ID: N4B

SAMPLE ID: B1, B2, B3, B4

STATIC WATER LEVEL (m)

SAMPLE DEPTH (m)

SAMPLING DATE 85/08/23

SAMPLING TIME:

Start 9:15

Finish 9:40

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.78	
Ec (umhos/cm)	1370	
Eh (millivolts)		
TEMP. (°C)	18	
ALKALINITY (mg/l $CaCO_3$)	172	@ 4.48
	178	@ 4.22

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
	One litre		B3	2
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	250 ml		B2	1
	500 ml *		B4	2

REMARKS: * Bottle ≃4/5 Full.

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 4.42

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 3.87

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailing

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 9:15

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 3.99 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/09/27	85/09/27	
METHOD OF SHIPMENT	Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3, B4	

NOTES: N4B 85/08/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Langley Bay

LOCATION ID: N5A

SAMPLE ID B1 to B8

STATIC WATER LEVEL (m) 0.82

SAMPLE DEPTH (m)

SAMPLING DATE 85/08/23

SAMPLING TIME:

Start 6:15

Finish 7:10

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.74	
Ec (umhos/cm)	467	
Eh (millivolts)		
TEMP. (°C)	19	
ALKALINITY (mg/l CaCO$_3$)	196 @ 4.48	
	200 @ 4.15	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		B5, B6, B7, B8	2
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1, B2		
	250 ml		B3, B4	1

REMARKS Collected 6 litre containers, transported and combined into 1 container for duplicate sample.

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 12.18

WELL DIA. (m) 0.035

BORE VOLUME (m³)

DEPTH TO SCREEN (m) 11.67

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailer

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 6:20

pH AFTER MEASUREMENT 7.01 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 10.02 FOR STANDARD SOLUTION pH 10.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

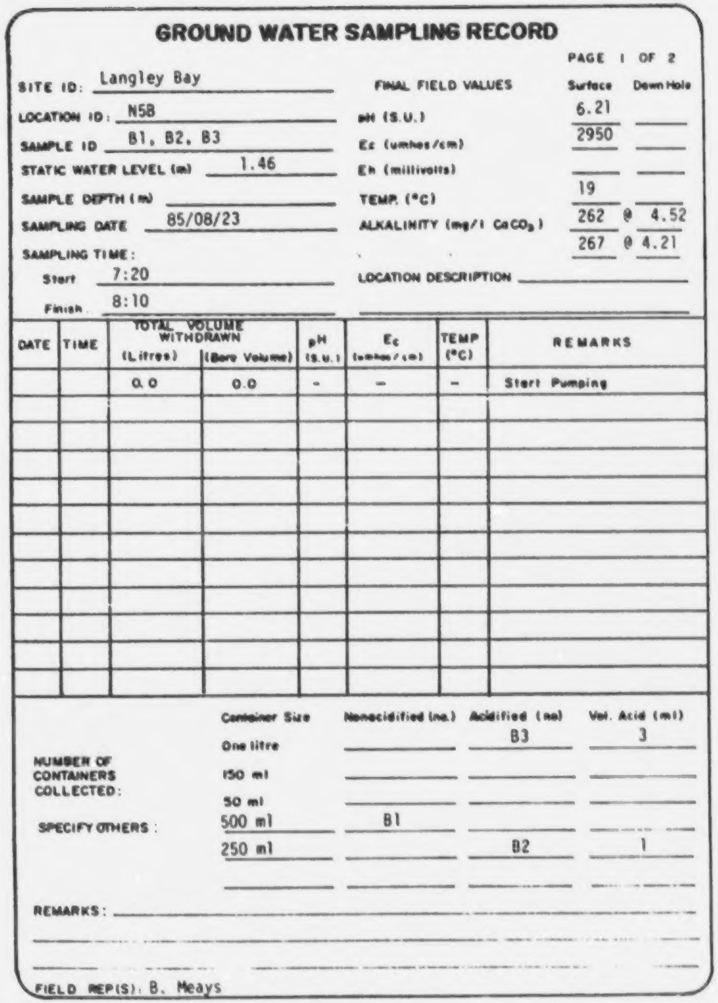
LAB(S) SHIPPED TO

DATE(S) SHIPPED

METHOD OF SHIPMENT

SAMPLE CLASSIFICATION

NOTES N5A 85/08/23



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Langley Bay

LOCATION ID: N5B

SAMPLE ID B1, B2, B3

STATIC WATER LEVEL (m) 1.46

SAMPLE DEPTH (m)

SAMPLING DATE 85/08/23

SAMPLING TIME:

Start 7:20

Finish 8:10

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.21	
Ec (umhos/cm)	2950	
Eh (millivolts)		
TEMP. (°C)	19	
ALKALINITY (mg/l $CaCO_3$)	262	@ 4.52
	267	@ 4.21

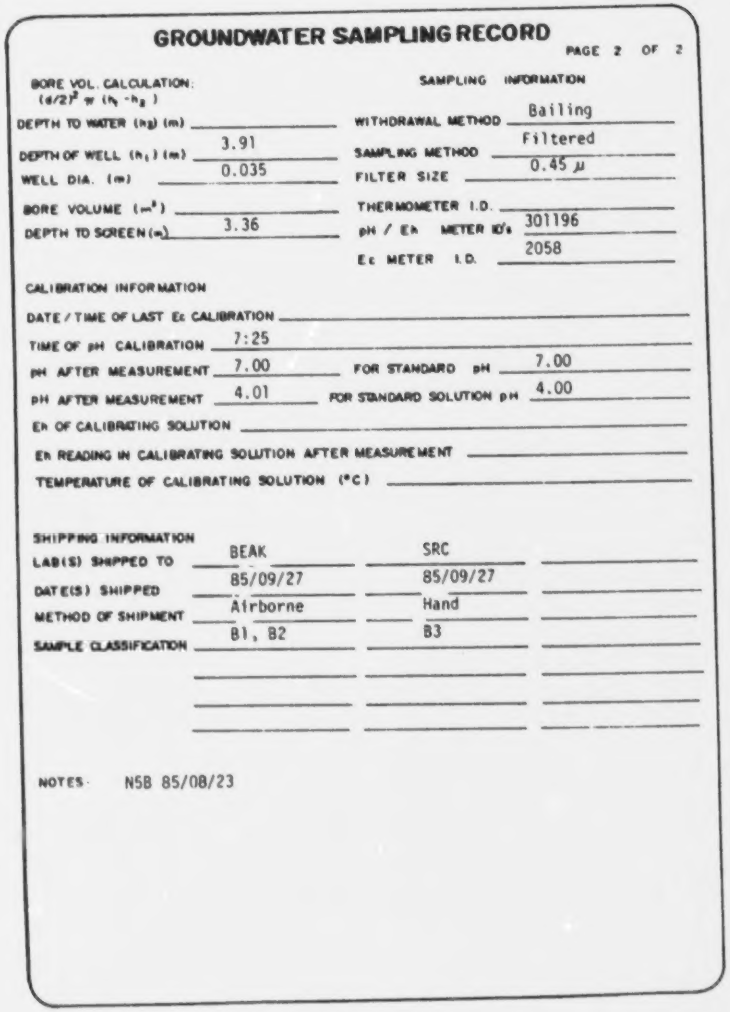
LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B3	3
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	250 ml		B2	1

REMARKS:

FIELD REP(S): B. Meays



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 3.91

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 3.36

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailing

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 7:25

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION			
LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/09/27	85/09/27	
METHOD OF SHIPMENT	Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3	

NOTES: N5B 85/08/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Langley Bay
LOCATION ID: N5C
SAMPLE ID B1, B2
STATIC WATER LEVEL (m) 1.47
SAMPLE DEPTH (m)
SAMPLING DATE 85/08/23
SAMPLING TIME:
Start 8:15
Finish 8:35

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	5.16	
Ec (umhos/cm)	4450	
Eh (millivolts)		
TEMP. (°C)	18	
ALKALINITY (mg/l $CaCO_3$)	22	@ 4.47
	24	@ 4.23

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
One litre			
150 ml			
50 ml			
SPECIFY OTHERS 500 ml	B1		
250 ml		B2	1

REMARKS: B2 only 2/3 full.

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m) 2.60
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 2.10.

SAMPLING INFORMATION
WITHDRAWAL METHOD Bailing
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION 8:20
pH AFTER MEASUREMENT 7.01 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION
LAB(S) SHIPPED TO
DATE(S) SHIPPED
METHOD OF SHIPMENT
SAMPLE CLASSIFICATION

NOTES: N5C 85/08/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: N6A

SAMPLE ID B1, B2, B3, B4, B5

STATIC WATER LEVEL (m) 1.22

SAMPLE DEPTH (m)

SAMPLING DATE 85/08/25

SAMPLING TIME:

Start 3:00

Finish 3:35

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.46	
Ec (umhos/cm)	910	
Eh (millivolts)		
TEMP. (°C)	12	
ALKALINITY (mg/l $CaCO_3$)	362	@ 4.45
	365	@ 4.15

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B4	3
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1	B5	2
	250 ml		B2	1
	30 ml	B3		

REMARKS: Used 3 filters.

FIELD REP(S). B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION: $(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 11.63

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 11.00

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailing

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I.D

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 3:10

pH AFTER MEASUREMENT 6.99 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 9.98 FOR STANDARD SOLUTION pH 10.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	SRC		
DATE(S) SHIPPED	85/09/27		
METHOD OF SHIPMENT	Hand		
SAMPLE CLASSIFICATION	B4		

NOTES: N6A 85/08/25

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: , N6B
SAMPLE ID B1, B2, B3, B4
STATIC WATER LEVEL (m) 0.92
SAMPLE DEPTH (m)
SAMPLING DATE 85/08/25
SAMPLING TIME:
Start 3:40
Finish. 4:05

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.24	
Ec (umhos/cm)	2680	
Eh (millivolts)		
TEMP. (°C)	12	
ALKALINITY (mg/l $CaCO_3$)	220	@ 4.52
	228	@ 4.18

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	–	Start Pumping

NUMBER OF CONTAINERS COLLECTED	Container Size	Nonacidified (no.)	Acidified (no)	Vol Acid (ml)
	One litre		B3, B4	3
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1		
	250 ml		B2	1

REMARKS.

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m) 5.76
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 5.15

SAMPLING INFORMATION
WITHDRAWAL METHOD Bailing
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION 3:35
pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 3.99 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION
LAB(S) SHIPPED TO SRC
DATE(S) SHIPPED 85/09/27
METHOD OF SHIPMENT Hand
SAMPLE CLASSIFICATION B3

NOTES N6B 85/08/25

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main
LOCATION ID: N6C
SAMPLE ID: B1, B2, B3, B4
STATIC WATER LEVEL (m): 0.85
SAMPLE DEPTH (m):
SAMPLING DATE: 85/08/25
SAMPLING TIME:
Start: 4:10
Finish: 4:35

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	5.95	
Ec (umhos/cm)	3470	
Eh (millivolts)		
TEMP. (°C)	12	
ALKALINITY (mg/l $CaCO_3$)	143	@ 4.45
	146	@ 4.21

LOCATION DESCRIPTION:

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B3	3
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1	B4	2
	250 ml		B2	1

REMARKS:

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m):
DEPTH OF WELL (h_1) (m): 4.39
WELL DIA. (m): 0.035
BORE VOLUME (m^3):
DEPTH TO SCREEN (m): 3.93

SAMPLING INFORMATION
WITHDRAWAL METHOD: Bailing
SAMPLING METHOD: Filtered
FILTER SIZE: 0.45 µ
THERMOMETER I.D.:
pH / Eh METER ID's: 301196
Ec METER I.D.: 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION:
TIME OF pH CALIBRATION: 3:35
pH AFTER MEASUREMENT 7.01 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION:
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT:
TEMPERATURE OF CALIBRATING SOLUTION (°C):

SHIPPING INFORMATION
LAB(S) SHIPPED TO: SRC
DATE(S) SHIPPED: 85/09/27
METHOD OF SHIPMENT: Hand
SAMPLE CLASSIFICATION: B3

NOTES: Piezometer bailed out on 85/08/23.
N6C 85/08/25

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: N6D

SAMPLE ID B1, B2, B3, B4

STATIC WATER LEVEL (m) 0.99

SAMPLE DEPTH (m)

SAMPLING DATE 85/08/25

SAMPLING TIME:

Start 4:40

Finish 5:00

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	5.79	
Ec (umhos/cm)	3350	
Eh (millivolts)		
TEMP. (°C)	13	
ALKALINITY (mg/l CaCO$_3$)	107	@ 4.46
	109	@ 4.22

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

	Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
	One litre		B4	3
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1		
	250 ml		B2	1
	30 ml	B3		

REMARKS:

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h$_2$) (m)

DEPTH OF WELL (h$_1$) (m) 3.63

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 2.97

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailing

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 3:35

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO SRC

DATE(S) SHIPPED 85/09/27

METHOD OF SHIPMENT Hand

SAMPLE CLASSIFICATION B4

NOTES: Piezometer bailed out on 85/08/23.
N6D 85/08/25

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: N6E

SAMPLE ID B1, B2, B3

STATIC WATER LEVEL (m) 0.90

SAMPLE DEPTH (m)

SAMPLING DATE 85/08/25

SAMPLING TIME:

Start 5:10

Finish 5:30

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.06	
Ec (umhos/cm)	3030	
Eh (millivolts)		
TEMP. (°C)	14	
ALKALINITY (mg/l $CaCO_3$)	182	@ 4.46
	186	@ 4.19

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre			
	150 ml			
	50 ml			
SPECIFY OTHERS.	500 ml	B1	B3	
	250 ml		B2	1

REMARKS:

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 2.51

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 1.95

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailed

SAMPLING METHOD Filtered

FILTER SIZE 0.45 μ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 3:35

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.00 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO SRC

DATE(S) SHIPPED 85/09/27

METHOD OF SHIPMENT Hand

SAMPLE CLASSIFICATION B3

NOTES: Piezometer bailed out on 85/08/23.
N6E 85/08/25

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM2B

SAMPLE ID B1, B2, B3, B4

STATIC WATER LEVEL (m) 3.64

SAMPLE DEPTH (m)

SAMPLING DATE 85/08/25

SAMPLING TIME:

Start 2:30

Finish 2:55

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.46	
Ec (umhos/cm)	2830	
Eh (millivolts)	—	
TEMP. (°C)	8	
ALKALINITY (mg/l $CaCO_3$)	637	@ 4.45
	644	@ 4.20

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	-	Start Pumping

	Container Size	Nonacidified (no)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED	One litre		B4	4
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1		
	250 ml		B2	2
	4/5 of 1 litre		B3	3

REMARKS:

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$

DEPTH TO WATER (h_2) (m)

DEPTH OF WELL (h_1) (m) 7.55

WELL DIA. (m) 0.035

BORE VOLUME (m^3)

DEPTH TO SCREEN (m) 6.97

SAMPLING INFORMATION

WITHDRAWAL METHOD Bailed

SAMPLING METHOD Filtered

FILTER SIZE 0.45 µ

THERMOMETER I.D.

pH / Eh METER ID's 301196

Ec METER I.D. 2058

CALIBRATION INFORMATION

DATE / TIME OF LAST Ec CALIBRATION

TIME OF pH CALIBRATION 2:32

pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00

pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00

Eh OF CALIBRATING SOLUTION

Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT

TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	SRC		
DATE(S) SHIPPED	85/09/27		
METHOD OF SHIPMENT	B3, B4		
SAMPLE CLASSIFICATION			

NOTES Piezometer bailed out previous day.
GM2B 85/08/25

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar
LOCATION ID: GM3B
SAMPLE ID B1, B2, B3, B4
STATIC WATER LEVEL (m) 2.07
SAMPLE DEPTH (m)
SAMPLING DATE 85/08/24
SAMPLING TIME:
Start 2:23
Finish 2:46

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.02	
Ec (umhos/cm)	4000	
Eh (millivolts)		
TEMP. (°C)	18	
ALKALINITY (mg/l $CaCO_3$)	234 @	4.52
	245 @	4.14

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	–	–	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B3, B4	3
	150 ml			
	50 ml			
SPECIFY OTHERS:	500 ml	B1		
	250 ml		B2	1

REMARKS:

FIELD REP(S) B. Meays/D. Downing

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m) 10.41
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 9.90

SAMPLING INFORMATION
WITHDRAWAL METHOD Bailer
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION 2:25
pH AFTER MEASUREMENT 4.00 FOR STANDARD pH 4.00
pH AFTER MEASUREMENT 7.00 FOR STANDARD SOLUTION pH 7.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION
LAB(S) SHIPPED TO SRC
DATE(S) SHIPPED 85/09/27
METHOD OF SHIPMENT Hand
SAMPLE CLASSIFICATION B3

NOTES GM3B 85/08/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID. Gunnar
LOCATION ID: GM3D
SAMPLE ID B1, B2, B3, B4
STATIC WATER LEVEL (m) 1.72
SAMPLE DEPTH (m)
SAMPLING DATE 85/08/24
SAMPLING TIME:
Start 2:50
Finish 3:14

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.60	
Ec (umhos/cm)	2970	
Eh (millivolts)		
TEMP. (°C)	17	
ALKALINITY (mg/l CaCO$_3$)	418 @ 4.47	
	422 @ 4.13	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

Container Size	Nonacidified (no)	Acidified (no)	Vol Acid (ml)
One litre		B3, B4	3
150 ml			
50 ml			

SPECIFY OTHERS

500 ml	B1		
250 ml		B2	1

REMARKS

FIELD REP(S) D. Downing/B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m) 5.13
WELL DIA. (m) 0.035
BORE VOLUME (m^3)
DEPTH TO SCREEN (m) 4.28

SAMPLING INFORMATION
WITHDRAWAL METHOD Bailer
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D.
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION 2:25
pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 4.01 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION
LAB(S) SHIPPED TO SRC
DATE(S) SHIPPED 85/09/27
METHOD OF SHIPMENT Hand
SAMPLE CLASSIFICATION B3

NOTES Piezometer bailed previous day.
GM3D 85/08/24

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID. Gunnar Central
LOCATION ID: GC5C
SAMPLE ID B1, B2, B3
STATIC WATER LEVEL (m) 1.43
SAMPLE DEPTH (m) ____
SAMPLING DATE 85/08/23
SAMPLING TIME:
Start 9:45
Finish. 10:10

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	6.69	
Ec (umhos/cm)	2000	
Eh (millivolts)		
TEMP. (°C)	18	
ALKALINITY (mg/l $CaCO_3$)	256 @	4.48
	258 @	4.21

LOCATION DESCRIPTION ____

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

	Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
NUMBER OF CONTAINERS COLLECTED:	One litre		B3	3
	150 ml			
	50 ml			
SPECIFY OTHERS.	500 ml	B1		
	250 ml		B2	1

REMARKS: ____

FIELD REP(S) B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m) ____
DEPTH OF WELL (h_1) (m) 4.26
WELL DIA. (m) 0.035
BORE VOLUME (m^3) ____
DEPTH TO SCREEN (m) 3.81

SAMPLING INFORMATION
WITHDRAWAL METHOD Bailing
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D. ____
pH / Eh METER ID's 301196
Ec METER I.D. 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION ____
TIME OF pH CALIBRATION 9:48
pH AFTER MEASUREMENT 7.00 FOR STANDARD pH 7.00
pH AFTER MEASUREMENT 3.99 FOR STANDARD SOLUTION pH 4.00
Eh OF CALIBRATING SOLUTION ____
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT ____
TEMPERATURE OF CALIBRATING SOLUTION (°C) ____

SHIPPING INFORMATION
LAB(S) SHIPPED TO ____
DATE(S) SHIPPED ____
METHOD OF SHIPMENT ____
SAMPLE CLASSIFICATION ____

NOTES. GC5C 85/08/23

GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID: Gunnar - St. Mary's Channel
LOCATION ID: SMI
SAMPLE ID: B1, B2, B3, B4
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE: 85/08/24
SAMPLING TIME:
Start: 1:50
Finish: 2:15

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)	7.94	
Ec (umhos/cm)	58	
Eh (millivolts)		
TEMP. (°C)	16	
ALKALINITY (mg/l CaCO$_3$)	14 @ 4.43	
	16 @ 4.22	

LOCATION DESCRIPTION

DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED

	Container Size	Nonacidified (no.)	Acidified (no.)	Vol. Acid (ml)
	One litre		B4	2
	150 ml			
	50 ml			
SPECIFY OTHERS	500 ml	B1		
	250 ml		B2	1
	30 ml	B3		

REMARKS: Water that was used for rinse water for bottles and sample processing.

FIELD REP(S): B. Meays

GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m)
WELL DIA. (m)
BORE VOLUME (m^3)
DEPTH TO SCREEN (m)

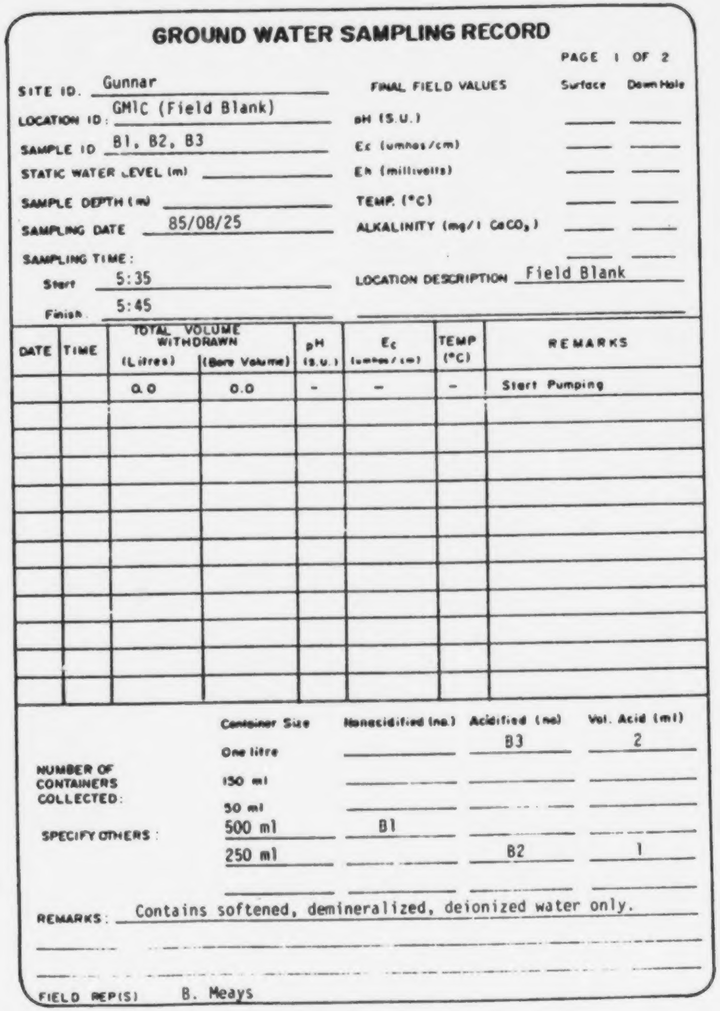
SAMPLING INFORMATION
WITHDRAWAL METHOD: Surface Scooped
SAMPLING METHOD: Filtered
FILTER SIZE: 0.45 μ
THERMOMETER I.D.
pH / Eh METER ID's: 301196
Ec METER I.D.: 2058

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION: 1:55
pH AFTER MEASUREMENT: 7.02 FOR STANDARD pH: 7.00
pH AFTER MEASUREMENT: 10.00 FOR STANDARD SOLUTION pH: 10.00
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/09/27	85/09/27	
METHOD OF SHIPMENT	Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B4	

NOTES: SM1 85/08/24



GROUND WATER SAMPLING RECORD

PAGE 1 OF 2

SITE ID. Gunnar
LOCATION ID: GMIC (Field Blank)
SAMPLE ID B1, B2, B3
STATIC WATER LEVEL (m)
SAMPLE DEPTH (m)
SAMPLING DATE 85/08/25
SAMPLING TIME:
Start 5:35
Finish 5:45

FINAL FIELD VALUES	Surface	Down Hole
pH (S.U.)		
Ec (umhos/cm)		
Eh (millivolts)		
TEMP. (°C)		
ALKALINITY (mg/l $CaCO_3$)		

LOCATION DESCRIPTION Field Blank

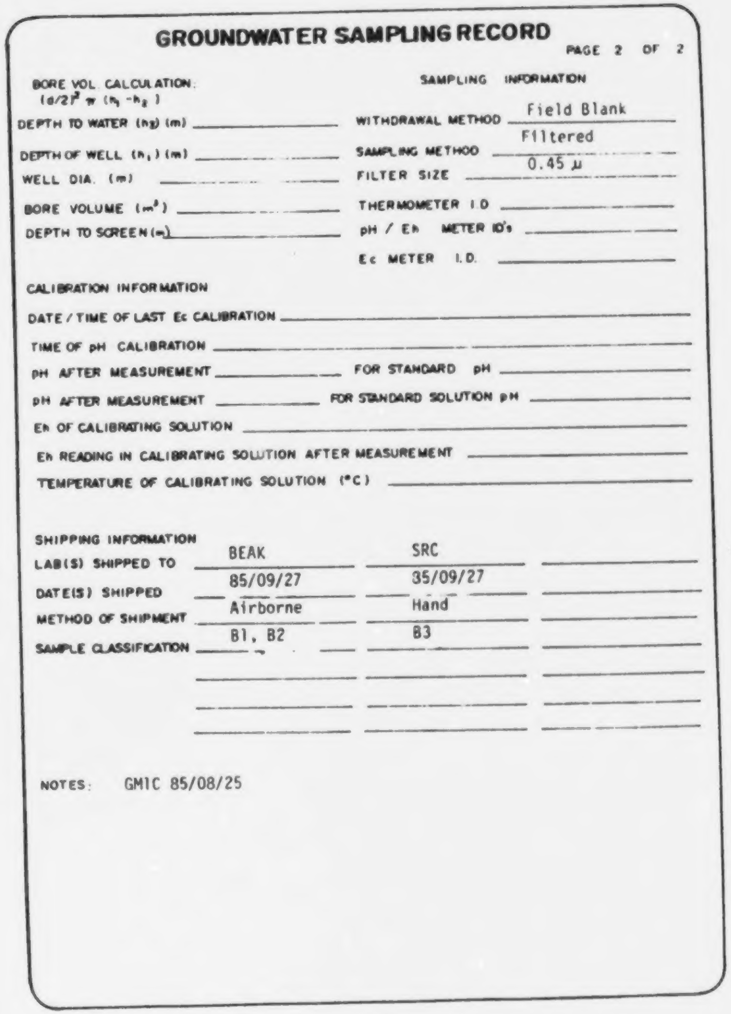
DATE	TIME	TOTAL VOLUME WITHDRAWN (Litres)	TOTAL VOLUME WITHDRAWN (Bore Volume)	pH (S.U.)	Ec (umhos/cm)	TEMP (°C)	REMARKS
		0.0	0.0	-	-	-	Start Pumping

NUMBER OF CONTAINERS COLLECTED:

Container Size	Nonacidified (no.)	Acidified (no)	Vol. Acid (ml)
One litre		B3	2
150 ml			
50 ml			
SPECIFY OTHERS: 500 ml	B1		
250 ml		B2	1

REMARKS: Contains softened, demineralized, deionized water only.

FIELD REP(S) B. Meays



GROUNDWATER SAMPLING RECORD

PAGE 2 OF 2

BORE VOL. CALCULATION:
$(d/2)^2 \pi (h_1 - h_2)$
DEPTH TO WATER (h_2) (m)
DEPTH OF WELL (h_1) (m)
WELL DIA. (m)
BORE VOLUME (m^3)
DEPTH TO SCREEN (m)

SAMPLING INFORMATION
WITHDRAWAL METHOD Field Blank
SAMPLING METHOD Filtered
FILTER SIZE 0.45 µ
THERMOMETER I.D
pH / Eh METER ID's
Ec METER I.D.

CALIBRATION INFORMATION
DATE / TIME OF LAST Ec CALIBRATION
TIME OF pH CALIBRATION
pH AFTER MEASUREMENT FOR STANDARD pH
pH AFTER MEASUREMENT FOR STANDARD SOLUTION pH
Eh OF CALIBRATING SOLUTION
Eh READING IN CALIBRATING SOLUTION AFTER MEASUREMENT
TEMPERATURE OF CALIBRATING SOLUTION (°C)

SHIPPING INFORMATION

LAB(S) SHIPPED TO	BEAK	SRC	
DATE(S) SHIPPED	85/09/27	85/09/27	
METHOD OF SHIPMENT	Airborne	Hand	
SAMPLE CLASSIFICATION	B1, B2	B3	

NOTES: GMIC 85/08/25

5.4.2 Groundwater Level Readings

The following sheets summarize the groundwater level records taken during various campaigns.

The groundwater level readings were all made with respect to the top of the pipe to eliminate any errors resulting from a change in ground surface elevation.

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar Tailings Pile FIELD REP. B. Meays PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N1B	Dec.10/84			
N1C	Dec.10/84		5.88	101.00
N1D	Dec.10/84		5.88	101.01
N2A	Dec. 6/84		1.66	100.41
N2B	Dec. 6/84		1.70	100.36
N2C	Dec. 6/84		2.54	99.40
N2D	Dec. 6/84		1.48	100.39
N3A	Dec. 7/84		1.07 (F)	98.65
N3B	Dec. 7/84		1.53 (F)	98.32
N3C	Dec. 7/84		1.56	98.04
N3D	Dec. 7/84		1.11 (F)	98.56
N3E	Dec. 8/84		11.25	87.78
N3F	Dec. 7/84		7.70	91.33
N3G	Dec. 7/84		1.23	97.79
N4A	Dec. 8/84		4.92	78.67
N4B	Dec. 8/84		4.08	79.42
N4C	Dec. 8/84		1.99	81.52
N4D	Dec. 8/84		1.66	82.32
N5A	Dec. 9/84		11.25	59.91
N5B	Dec. 9/84		3.46	67.71
N5C	Dec. 9/84		1.80	69.32

REMARKS

BOREHOLE – Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar FIELD REP. B. Meays PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N3AB	84/12/03	10:26	2.65	97.07
N3C	84/12/03	14:30	1.52	98.08
N3D	84/12/03	13:38	1.12	98.55
N3E	84/12/07	11:00	7.70	91.33
N3F	84/12/07	11:00	8.43	90.60
N4A	84/12/08	12:15	4.92	78.67
N4B	84/12/08	14:35	4.08	79.42
N4C	84/12/08	13:00	1.99	81.52
N4D	84/12/08	13:45	1.66	82.32

REMARKS From Water Sampling Sheets.

BOREHOLE – Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar FIELD REP. B. Meays PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N1C	85/12/10	15:17	5.88	101.00
N2A	84/12/06	12:51	1.66	100.41
N2A	84/12/03	11:30	1.66	100.41
N2B	84/12/06	10:56	1.70	100.36
N2B	84/12/03	11:30	1.70	100.36
N2D	84/12/03	11:30	1.48	100.39
N2C	84/12/03	11:30	2.58	99.36
N3A	84/12/07	12:49	1.07(F)	98.65
N2D	84/12/06	10:15	1.48	100.39
N3E	84/12/07	14:48	11.25	87.78
N3C	84/12/04	12:03	1.46	98.14
N4A	84/12/08	12:50	4.92	78.67
N3F	84/12/07	14.46	7.70	91.33
N4C	84/12/08	13:08	1.99	81.52
N4B	84/12/08	15:10	4.08	79.42
N5A	84/12/09	14:29	11.25	59.91
N4D	84/12/08	14:28	1.65	82.33
N5C	84/12/09	12:23	1.80	69.32
N5B	84/12/09	13:26	3.46	67.71

REMARKS: From Slug Test Data Sheets.

BOREHOLE - Top of Ground   Well — Top of Casing   (F) - Frozen

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GROUNDWATER LEVEL RECORD

SITE ID Gunnar Tailings Pile FIELD REP. S. Sponton PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N1B	85/01/12		3.23 (F)	104.02
N1C	85/01/12		5.84	101.04
N1D			5.80	101.09
N2A	85/01/12		1.75	100.32
N2B	85/01/12		1.69	100.37
N2C	85/01/12		1.58 (F)	100.36
N2D	85/01/12		1.54	100.33
N3A	85/01/12		1.40 (F)	98.32
N3B	85/01/12		1.50 (F)	98.35
N3C	85/01/12		1.07 (F)	98.53
N3D	85/01/12		1.10 (F)	98.57
N3E	85/01/12		0.70 (F)	98.33
N3F	85/01/12		1.03 (F)	98.00
N3G	85/01/12		0.60 (F)	98.42
N4A	85/01/12		(F)	
N4B	85/01/12		(F)	
N4C	85/01/12		1.73	81.78
N4D	85/01/12		1.60	82.38
N5A	85/01/12		1.72	69.44
N5B	85/01/12		2.29	68.88
N5C	85/01/12		2.40	68.72

REMARKS: N1B possibly plugged - not frozen.

BOREHOLE - Top of Ground   Well — Top of Casing   (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar FIELD REP S. Sponton PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N5A	85/02/24		1.15	70.01
N5B	85/02/24		2.65	68.52
N5C	85/02/24		2.62	68.50
N4A	85/02/24		0.86 (F)	82.73
N4B	85/02/24		1.56 (F)	81.94
N4C	85/02/24		2.25	81.26
N4D	85/02/24		2.05 (F)	81.93

REMARKS Nest 5 was bailed (N5A was not completely purged.)

BOREHOLE - Top of Ground Well – Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar FIELD REP B. Meays PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N1B	85/03/05	2:10 pm	Dry at 4.35	102.90
N1C	85/03/05	2:20 pm	5.96	100.92
N1D	85/03/05		Plugged with snow	
N2A	85/03/05	3:20 pm	1.80 (F)	100.27
N2B	85/03/05	3:20 pm	1.70 (F)	100.36
N2C (1)	85/03/05	3:20 pm	1.76 (F)	100.18
N2D	85/03/05	3:25 pm	1.60 (F)	100.27
N3	All seven frozen ≈0.3 m below ground			≈ 98.35
N5A	85/03/06	9:30 am	3.04	68.12
N5B	85/03/06	9:30 am	3.08	68.09
N5C	85/03/06	9:30 am	Dry at 2.60	68.52
N4A	85/03/06	2:00 pm	0.87 (F)	82.72
N4B	85/03/06	2:00 pm	1.54 (F)	81.96
N4C	85/03/06	2:00 pm	2.35	81.16
N4D	85/03/06	2:00 pm	2.40 (F)	81.58

REMARKS (1) indicates slug stuck in Piezometer

BOREHOLE - Top of Ground Well – Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar Main FIELD REP B. Meays PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER LOCATION (m) BELOW DATUM	GROUNDWATER LOCATION ELEVATION (m)
N6A	85/03/09	15:35	11.01	89.36
N6A	85/03/10	14:35	9.63	90.74
N6B	85/03/09	15:37	4.84	95.54
N6B	85/03/10	14:34	2.32	98.06
N6C	85/03/09	15:38	3.49	96.74
N6C	85/03/10	14:33	1.25	98.98
N6D	85/03/09	15:40	2.81	97.61
N6D	85/03/10	14:30	1.31	99.11
N6E	85/03/09	15:41	2.28	98.03
N6E	85/03/10	14:30	1.23	99.08
GM9B	85/03/10	15:32	4.50	97.31
GM9B	85/03/11	10:40	4.48 (1)*	97.33
GM9B	85/03/12	8:10	4.49 (1)	97.32
GM9C	85/03/10	15:30	2.76 (1)	98.95
GM9C	85/03/11	10:42	2.44 (1)	97.27
GM9C	85/03/12	8:15	2.49 (1)	99.22
GM17C	85/03/13	13:15	1.56 (1)	98.39
GM17B	85/09/13	13:15	2.74 (1)	97.28
GM4B	85/03/13	13:30	2.91 (1)	98.47

REMARKS *(1) indicates piezometer was bailed out after water level reading was taken.

BOREHOLE - Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar Main FIELD REP R. Boivin PAGE 1 OF 3

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER LOCATION (m) BELOW DATUM	GROUNDWATER LOCATION ELEVATION (m)
GM9B	85/03/10	11:04 am	Dry	
GM9B	85/03/10	11:16 am	Trace	
GM9B	85/03/10	11:30 am	Trace	
GM9C	85/03/10	11:50 am	50 mm @ bottom	
GM17B	85/03/12	9:30 am	Trace	
GM17B	85/03/12	9:48 am	2.05	97.97
GM17C	85/03/12	9:50 am	Dry	
GM17C	85/03/12	10:00 am	Trace	
GM17B	85/03/12	10:03 am	2.02	98.00
GM19B	85/03/12	1:20 pm	Dry	
GM19B	85/03/12	1:28 pm	4.11	97.54
GM19B	85/03/12	1:52 pm	3.80	97.85
GM19C	85/03/12	2:02 pm	2.71	99.28
GM19C	85/03/12	2:14 pm	2.63	99.36
GM4B	85/03/12	4:24 pm	4.93	96.45
GM4B	85/03/12	4:38 pm	4.80	96.58
GM13B	85/03/20	12:08 pm	3.40	97.58
GM13B	85/03/20	12:16 pm	3.40	97.58
GM12B	85/03/20	4:06 pm	Trace	
GM12B	85/03/20	4:16 pm	2.15	99.20
GM12A	85/03/20	4:17 pm	3.22	98.00
GM12A	85/03/20	4:33 pm	3.22	98.00
GM12B	85/03/20	4:31 pm	2.10	99.25

REMARKS

BOREHOLE - Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar Main FIELD REP R. Boivin PAGE 2 OF 3

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N2E	85/03/21	2:50 pm	7.76	94.41
N2E	85/03/21	2:40 pm	7.76	94.41
N2E	85/03/21	3:02 pm	7.76	94.41
N2E	85/03/21	3:33 pm	7.75	94.42
N2E	85/03/21	4:33 pm	7.74	94.43
N2F	85/03/22	4:13 pm	6.00	96.29
N2F	85/03/22	4:30 pm	5.95	96.34
N2F	85/03/22	5:00 pm	5.90	96.39
N2G	85/03/22	5:02 pm	3.83	98.41
N2G	85/03/22	5:16 pm	3.02	99.22
N2G	85/03/22	5:35 pm	2.35	99.89
N2G	85/03/22	5:53 pm	1.91	100.33
N2F	85/03/22	5:51 pm	5.79	96.50
N2G	85/03/23	10:00 am	1.32	100.92
N2H	85/03/23	12:06 pm	2.57	99.56
N2H	85/03/23	12:17 pm	1.73	100.40
(N2J) N2I	85/03/23	12:25 pm	2.30	99.88
N2H	85/03/23	1:47 pm	1.27	100.86
(N2J(N2I	85/03/23	1:48 pm	1.46	100.72
GC5B	85/03/23	5:17 pm	Trace	
GC5B	85/03/23	5:58 pm	(3.42) Trace	79.93
GC5C	85/03/23	5:56 pm	Dry	
LB2B	85/03/24	1:06 pm	3.92	66.32
LB2B	85/03/24	1:28 pm	3.85	66.39
LB2C	85/03/24	1:30 pm	Trace	

REMARKS N2J Should Be Labeled N2I.

BOREHOLE - Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar Main FIELD REP R. Boivin PAGE 3 OF 3

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
LB2C	85/03/24	2:47 pm	3.61	66.68
LB2B	85/03/24	2:49 pm	3.84	66.40
LB7B	85/03/25	10:19 am	25 mm @ bottom	
LB7B	85/03/25	10:30 am	4.42	65.82
LB7C	85/03/25	10:33 am	Dry	
LB7C	85/03/25	10:44 am	Trace	
LB7B	85/03/25	10:46 am	4.42	65.82

REMARKS

BOREHOLE - Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar Main FIELD REP. S. Sponton PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER LOCATION (m) BELOW DATUM	GROUNDWATER LOCATION ELEVATION (m)
GM4B	85/03/15	8:45 am	2.07	99.31
(GM17A)GM17C	85/03/15	9:25 am	1.53	98.42
GM17B	85/03/15	9:25 am	1.21	98.81
GM9B	85/03/15	9:40 am	4.27	97.54
GM9C	85/03/15	9:40 am	2.47	99.24
GM19C	85/03/15	9:55 am	1.86	100.13
GM19B	85/03/15	9:55 am	2.17	99.48
GM19B	85/03/17	3:00 pm	2.15	99.50
GM19C	85/03/17	3:00 pm	1.83	100.16

REMARKS: All were bailed
GM17A Should Be Labeled GM17C.

BOREHOLE - Top of Ground Well - Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar Main FIELD REP R. Boivin PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER LOCATION (m) BELOW DATUM	GROUNDWATER LOCATION ELEVATION (m)
N1E	85/03/26	17:07	7.27	99.60
N1E	85/03/26	17:22	6.98	99.89
N1E	85/03/26	17:50	6.55	100.32
GM3B	85/03/28	15:37	10.15	92.21
GM3B	85/03/28	16:09	10.10	92.26
GM3C	85/03/28	16:12	2.50	100.00
GM3C	85/03/28	16:35	2.33	100.17
GM3D	85/03/28	16:33	2.45	100.13
GM3B	85/03/28	16:37	10.07	92.29
GM3D	85/03/28	16:50	2.42	100.16
GM3C	85/03/28	16:52	2.33	100.17
GM3E	85/03/28	17:13	2.88	99.60
GM3E	85/03/28	17:20	2.34	100.14
GM3D	85/03/28	17:25	2.42	100.16
GM3C	85/03/28	17:27	2.34	100.16
GM3B	85/03/28	17:29	10.05	92.31
GM3E	85/03/28	17:35	2.27	100.21
GM2B	85/03/29	14:23	6.09	98.46
GM2B	85/03/29	14:35	5.71	98.84
GM2B	85/03/29	15:15	4.88	99.67
GM2C	85/03/29	16:30	Dry	
GM2C	85/03/29	16:40	Dry	

REMARKS:

BOREHOLE - Top of Ground Well - Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar FIELD REP. B. Meays PAGE 1 OF 2

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N1C	85/03/10	10:00	5.98	100.90
N1E	85/03/29	10:00	6.09	100.78
N2E	85/03/25	12:30	7.60	94.57
N2G	85/03/25	11:20	1.32	100.92
N2H	85/03/25	10:15	1.24	100.89
N2I	85/03/25	09:00	1.30	100.88
N6A	85/03/25	15:30	9.86	90.51
N6B	85/03/12	14:15	2.79	97.59
N6C	85/03/12	13:00	1.30	98.93
N6D	85/03/12	10:20	1.30	99.12
N6E	85/03/12	08:50	1.20	99.11
GM2B	85/03/30	12:30	4.11	100.44
GM3B	85/03/30	11:30	9.83	92.53
GM3C	85/03/30	10:10	2.29	100.21
GM4B	85/03/20	13:10	1.97	99.41
GM9C	85/03/13	10:00	2.49	99.22
GM12A	85/03/24	10:00	2.66	98.56
GM12B	85/03/24	11:00	1.88	99.47
GM13A	85/03/23	10:00	6.09	94.83
GM13B	85/03/23	10:50	2.61	98.37
GM17B	85/03/19	14:00	1.99	98.03
GM17C	85/03/19	15:15	1.52	98.43
GM19B	85/03/21	10:00	2.12	99.53
GM19C	85/03/21	11:05	1.82	100.17
N5A	85/03/09	09:30	10.20	60.96
N5B	85/03/09	12:30	3.57	67.60
LB2B	85/03/26	11:20	3.56	66.68
LB2C	85/03/26	10:30	2.65	67.64

REMARKS: From Water Sampling Sheets.

BOREHOLE - Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar FIELD REP. B. Meays PAGE 2 OF 2

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
LB3C	85/03/28	15:00	3.71	66.53
LB7B	85/03/28	11:40	4.12	66.12

REMARKS: From Water Sampling Sheets.

BOREHOLE - Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar FIELD REP S. Sponton PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER LOCATION (m) BELOW DATUM	GROUNDWATER LOCATION ELEVATION (m)
GM6A	85/03/27	09:25	3.11	98.37
GM4B	85/03/27	13:01	1.89	99.49
GM9C	85/03/27	10:15	2.50	99.21
GM9B	85/03/27	10:05	4.23	97.58
GM13A	85/03/27	13:53	5.85	95.07
GM12B	85/03/29	10:26	1.81	99.54
GM17B	85/03/21	10:00	2.05	97.97
GM13B	85/03/27	13:57	2.18	98.80
GC5B	85/03/28	11:31	3.205	80.145
GM17C	85/03/21	13:10	1.51	99.44
LB2B	85/03/28	13:32	3.18	67.06
GC5C	85/03/28	11:38	3.78	79.65
N1C	85/03/11	09:25	5.98	100.90
LR2C	85/03/28	13:35	1.97	68.32
N5A	85/04/12	09:58	2.34	68.82
N1E	84/04/11	16:43	6.12	100.75
GM2B	85/04/11	17:35	4.09	100.46
N5B	85/04/12	10:11	2.81	68.36
GM3C	85/04/11	14:51	2.295	100.205
GM3B	85/04/11	14:25	6.165	96.195
GM3E	85/04/11	15:43	2.20	100.28
GM3D	84/04/11	15:15	2.34	100.24
GC5C	85/04/12	11:54	2.89	80.54
GM19B	85/04/11	18:59	2.30	99.35
LB2C	85/04/12	11:01	1.50	68.79
LB2B	85/04/12	10:49	1.62	68.62

REMARKS: From Slug Test Data Sheets.

BOREHOLE – Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar FIELD REP S. Sponton PAGE 1 OF 3

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER LOCATION (m) BELOW DATUM	GROUNDWATER LOCATION ELEVATION (m)
N5A	85/05/02		2.435	68.725
N5B	85/05/02		2.81	68.36
N5C	85/05/02		(F)	
LB2B	85/05/02		1.35	68.89
LB2C	85/05/02		1.225	69.065
LB7B	85/05/02		0.69	69.55
LB7C	85/05/02		0.10	70.12
LB3C	85/05/02		0.25	69.99
(LB3B) LB3A	85/05/02		1.68	68.54
GC5C	85/05/02		2.555	80.875
GC5B	85/05/02		2.24	81.11
N4A	85/05/02		(F)	
N4B	85/05/02		(F)	
N4C	85/05/02		(F)	
N4D	85/05/02		(F)	
GM9C	85/05/02		2.23	99.48
(GM17A)GM17C	85/05/02		0.58	99.37
GM17B	85/05/02		0.95	99.07
N3A	85/05/02		(F)	
N3B	85/05/02		(F)	

REMARKS: LB3B Should Be Labeled LB3A.
GM17A Should Be Labeled GM17C.

BOREHOLE – Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar FIELD REP S. Sponton PAGE 2 OF 3

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N3C	85/05/02		(F)	
N3D	85/05/02		(F)	
N3E	85/05/02		(F)	
N3F	85/05/02		(F)	
N3G	85/05/02		(F)	
N1E	85/05/02		6.16	100.71
GM3B	85/05/02		4.035	98.325
GM3C	85/05/02		2.15	100.35
GM3D	85/05/02		2.21	100.37
GM3E	85/05/02		2.105	100.375
N2A	85/05/02		(D)	
N2B	85/05/02		(D)	
N2C	85/05/02		(D)	
N2D	85/05/02		(D)	
N2E	85/05/02		1.57 (D)	100.60
N2G	85/05/02		(D)	
N2H	85/05/02		(D)	
(N2J) N2I	85/05/02		1.47	100.71
GM6B	85/05/02		(D)	
N6E	85/05/02		(F)	
N6D	85/05/02		(F)	
N6C	85/05/02		(F)	
N6B	85/05/02		(F)	

REMARKS (D) - Dry
N2J Should Be Labeled N2I.

BOREHOLE - Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar FIELD REP S. Sponton PAGE 3 OF 3

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
GM4B	85/05/02		1.285	100.095
GM19B	85/05/02		1.55	100.10
GM19C	85/05/02		1.29	100.70
GM13A	85/05/02		0.99	99.93
GM13B	85/05/02		1.08	99.90
GM2B	85/05/02		4.10	100.45
GM2C	85/05/02		4.03	100.42

REMARKS

BOREHOLE - Top of Ground Well — Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar FIELD REP S. Sponton PAGE 1 OF 3

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER LOCATION (m) BELOW DATUM	GROUNDWATER LOCATION ELEVATION (m)
GM19B	85/05/29		1.445 (D)	100.205
GM19C	85/05/29		1.31 (D)	100.68
GM13B	85/05/29		0.925	100.055
GM13A	85/05/29		0.59	100.33
GM3B	85/05/29		2.265	100.095
GM3C	85/05/29		1.545	100.955
GM3D	85/05/29		1.605	100.975
GM3E	85/05/29		1.44	101.04
N2A	85/05/29		1.98 (D)	100.09
N2B	85/05/29		2.08 (D)	99.98
N2C	85/05/29		1.75 (D)	100.19
N2D	85/05/29		1.67 (D)	100.20
N2E	85/05/29		1.11	101.06
N2G	85/05/29		1.26 (D)	100.98
N2H	85/05/29		1.20 (D)	100.93
(N2J) N2I	85/05/29		1.26	100.92
GM12B	85/05/29		0.35 (1)	101.00
GM12A	85/05/29		0.265 (1)	100.955
GM4B	85/05/29		1.41	99.97
N5A	85/05/29		1.36	69.80
N5B	85/05/29		2.15	69.02
N5C	85/05/29		2.06	69.06

REMARKS: (1) - above ground level
N2J Should Be Labeled N2I.

BOREHOLE - Top of Ground Well - Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar FIELD REP S. Sponton PAGE 2 OF 3

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER LOCATION (m) BELOW DATUM	GROUNDWATER LOCATION ELEVATION (m)
GC5C	85/05/29		(2)	
GC5B	85/05/29		(2)	
LB7A	85/05/29		(2)	
LB7B	85/05/29		(2)	
LB2B	85/05/29		0.92	69.32
LB2C	85/05/29		(2)	
N4D	85/05/29		2.01	81.97
N4C	85/05/29		(D)	
N4B	85/05/29		(D)	
N4A	85/05/29		1.31	82.28
GC5C	85/05/29		1.91 (D)	81.52
GC5B	85/05/29		1.89 (D)	81.46
N3A	85/05/29		0.665	98.305
N3B	85/05/29		0.18	98.80
N3C	85/05/29		0.625	98.415
N3D	85/05/29		0.55	98.49
N3E	85/05/29		0.69	98.34
N3F	85/05/29		0.13	98.90
N3G	85/05/29		0.66	98.36
GM17B	85/05/29		0.90	99.12
(GM17A) GM17C	85/05/29		0.92	99.03

REMARKS (2) - Inaccessible: Same level as lake
GM17A Should Be Labeled GM17C; GC5A Should Be Labeled GC5C

BOREHOLE - Top of Ground Well - Top of Casing (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar FIELD REP S. Sponton PAGE 3 OF 3

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N1E	85/05/29		6.09	100.78
N1D	85/05/29		4.40	102.49
N1A	85/05/29		(D)	
N6B	85/05/29		1.17	99.21
N6C	85/05/29		1.06	99.17
N6D	85/05/29		1.225	99.195
N6E	85/05/29		1.02	99.29
GM9C	85/05/29		2.05	99.66
GM6B	85/05/29		3.20 (D)	98.90
GM3B	85/05/29		4.06	98.30
GM2C	85/05/29		3.98	100.47

REMARKS

BOREHOLE – Top of Ground   Well – Top of Casing   (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar FIELD REP B. Meays PAGE 1 OF 2

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
GM19B	85/06/20	14:30	1.72 (F)	99.93
GM19C	85/06/20	14:30	1.75	100.24
GM4A	85/06/20		1.17	
GM4B	85/06/20		1.44	99.94
N6A	85/06/20		0.75	99.62
N6B	85/06/20		0.70	99.68
N6C	85/06/20		0.60	99.63
N6D	85/06/20		0.80	99.62
N6E	85/06/20		0.72	99.59
GM17B	85/06/20	14:53	0.95	99.07
GM17C	85/06/20	14:53	0.95	99.00
N3A	85/06/20	15:00	0.82	98.15
N3B	85/06/20	15:00	0.81	98.17
N3C	85/06/20	15:00	0.78	98.26
N3D	85/06/20	15:00	0.82	98.22
N3E	85/06/20	15:00	0.62	98.41
N3F	85/06/20	15:00	0.94	98.09
N3G	85/06/20	15:00	0.79	98.23
GM9C	85/06/20	15:08	1.96	99.75
GM6B	85/06/20		2.21 (F)	99.89
GM6A	85/06/20		4.06 (F)	97.92

REMARKS

BOREHOLE – Top of Ground   Well – Top of Casing   (F) - Frozen

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GROUNDWATER LEVEL RECORD

SITE ID Gunnar FIELD REP B. Meays PAGE 2 OF 2

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
GM2A	85/06/20		0.61 (D)	
GM2B	85/06/20		4.01	100.54
GM2C	85/06/20		3.93	100.52
N1E	85/06/20		6.03	100.84
N1F	85/06/20		4.53	102.48
N2A	85/06/20	16:00	1.99 (F)	100.08
N2B	85/06/20	16:00	2.08 (F)	99.98
N2C	85/06/20	16:00	1.76 (F)	100.18
N2D	85/06/20	16:00	1.68 (F)	100.19
N2E	85/06/20		1.07	101.10
N2F	85/06/20		1.05	101.24
N2G	85/06/20		1.27 (F)	100.97
N2H	85/06/20		1.20 (F)	100.93
(N2J) N2I	85/06/20		1.23 (F)	100.95
GM3A	85/06/20		1.23	
GM3B	85/06/20		1.69	100.67
GM3C	85/06/20		1.32	101.18
GM3D	85/06/20		1.42	101.16
GM3E	85/06/20		1.26	101.22
GM12A	85/06/20		0.30	100.92
GM12B	85/06/20		0.38	100.97

REMARKS N2J Should Be Labeled N2I

BOREHOLE – Top of Ground   Well – Top of Casing   (F) - Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar FIELD REP. B. Meays PAGE 1 OF 2

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N5A	85/06/22	12:32	1.91	69.25
N5B	85/06/22	12:36	1.41	69.76
N5C	85/06/22	12:37	0.99	70.13
N4D	85/06/22	11:28	1.58	82.40
N1C	85/06/23	13:50	6.09	100.79
N6B	85/06/23		0.72	99.66
N6C	85/06/23	15:15	0.62	99.61
N6D	85/06/23		0.81	99.61
N6E	85/06/23		0.73	99.58
N1E	85/06/23		6.04	100.83
N3A	85/06/23		0.84	98.13
N3D	85/06/24		0.81	98.23
GM3E	85/06/23		1.28	101.20
GM3B	85/06/23		1.68	100.68
GM2B	85/06/24		4.00	100.55
GM3D	85/06/23		1.43	101.15

REMARKS: From Water Sampling Sheets.

BOREHOLE – Top of Ground Well – Top of Casing (F) – Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar FIELD REP. B. Meays PAGE 2 OF 2

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N1C	85/08/24	08:25	5.72	101.16
N2E	85/08/25	15:20	0.97	101.20
N2G	85/08/24	15:45	1.08	101.16
N2H	85/08/24	16:22	1.05	101.08
N3A	85/08/24	14:47	1.08	97.89
N3E	85/08/24	06:30	0.56	98.47
N3F	85/08/24	07:15	0.77	98.26
N4A	85/08/23	08.35	1.18	82.41
N5A	85/08/23	06:15	0.82	70.34
N5B	85/08/23	07:20	1.46	69.71
N5C	85/08/23	08:15	1.47	69.65
N6A	85/08/25	15:00	1.22	99.15
N6B	85/08/25	15:40	0.92	99.46
N6C	85/08/25	16:10	0.85	99.38
N6D	85/08/25	16:40	0.99	99.43
N6E	85/08/25	17:10	0.90	99.41
GM2B	85/08/25	14:30	3.64	100.91
GM3B	85/08/24	14:23	2.07	100.29
GM3D	85/08/24	14:50	1.72	100.86
GC5C	85/08/23	09:45	1.43	82.00

REMARKS: From Water Sampling Sheets.

BOREHOLE – Top of Ground Well – Top of Casing (F) – Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar FIELD REP. B. Meays PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N1E	85/06/21	12:45	6.03	100.84
N1C	85/06/21	15:15	5.94	100.94
N3D	85/06/21	10:50	0.81	98.23
N3A	85/06/21	10:40	0.84	98.13
N5B	85/06/21	11:30	0.72	70.45
N3G	85/06/21	10:30	0.81	98.21
N6D	85/06/21	11:50	0.81	99.61
N6C	85/06/21	11:40	0.62	99.61
GM2B	85/06/21	16:00	4.00	100.55
N6E	85/06/21	12:00	0.73	99.58
GM4B	85/06/21	17:40	0.46	100.92
GM3B	85/06/21	19:00	1.50	100.86
GM13A	85/06/21	18:30	4.44	96.48
GM9C	85/06/21	16:30	1.94	99.77
GM17B	85/06/21	17:00	0.99	99.03
GM13B	85/06/21	18:30	2.34	98.64
GM19B	85/06/21	18:00	1.94	99.71
GM17C	85/06/21	17:15	0.99	98.96
GM19C	85/06/21	18:00	1.80	100.19

REMARKS: From Slug Test Data Sheets.

BOREHOLE – Top of Ground Well – Top of Casing (F) – Frozen

GROUNDWATER LEVEL RECORD

SITE ID Gunnar Main FIELD REP. B. Meays/D. Downing PAGE 1 OF 2

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N1E	85/08/23	8:36	5.83	101.04
N1F	85/08/23	8:44	4.52	102.49
N1D	85/08/23	8:43	4.41	102.48
N1C	85/08/23	8:45	5.72	101.16
GM3B	85/08/23	9:11	2.07	100.29
GM3C	85/08/23	9:13	1.64	100.86
GM3D	85/08/23	9:13	1.72	100.86
GM3E	85/08/23	9:14	1.57	100.91
N2A	85/08/23	9:29	1.90	100.17
N2B	85/08/23	9:31	2.06	100.00
N2C	85/08/23	9:32	1.75	100.19
N2D	85/08/23	9:33	1.54	100.33
N2E	85/08/23	9:35	0.97	101.20
N2G	85/08/23	9:35	1.08	101.16
N2H	85/08/23	9:37	1.05	101.08
N2I	85/08/23	9:37	1.11	101.07
GM2B	85/08/23	10:05	3.64	100.91
GM2C	85/08/23	10:07	3.51	100.94
N6B	85/08/23	10:24	0.92	99.46
N6C	85/08/23	10:25	0.85	99.38
N6D	85/08/23	10:25	0.99	99.43
N6E	85/08/23	10:26	0.90	99.41
GM9C	85/08/23	10:14	2.00	99.71
GM6A	85/08/23	10:20	1.49(F)	100.49
GM6B	85/08/23	10:26	3.22	98.88
N3E	85/08/23	10:51	0.56	98.47
N3F	85/08/23	10:51	0.77	98.26
N3G	85/08/23	10:52	1.17	97.85

REMARKS: Not Much Water In N1F, N1D. Hardly Any Water and Ice in N2A.
N2B - Ice Underneath. N2C - Ice or Maybe Old Slug. N2D - Ice. GM6B - Dry.

BOREHOLE – Top of Ground Well – Top of Casing (F) – Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar Main FIELD REP. B. Meays/ D. Downing PAGE 2 OF 2

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N3A	85/08/23	10:48	1.08	97.89
N3B	85/08/23	10:49	1.16	97.82
N3C	85/08/23	10:49	1.15	97.89
N3D	85/08/23	10:50	1.11	97.93

REMARKS:

BOREHOLE – Top of Ground Well – Top of Casing (F) – Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Langley Bay, Gunnar Central & Gunnar Main FIELD REP. B. Meays/ D. Downing PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
N5A	85/08/23	12:42	0.82	70.34
N5B	85/08/23	12:42	1.46	69.71
N5C	85/08/23	12:43	1.47	69.65
LB2B	85/08/23			
LB2C	85/08/23			
LB7B	85/08/23			
LB7C	85/08/23			
LB3A	85/08/23			
LB3C	85/08/23			
N4A	85/08/23	1:30	1.18	82.41
N4B	85/08/23	1:31	1.32	82.18
N4D	85/08/23	1:32	1.89	82.09
N4C	85/08/23	1:32	1.33	82.18
GC5B	85/08/23	1:51	1.47	81.88
GC5C	85/08/23	1:52	1.43	82.00
GM17B	85/08/23	2:46	1.52	98.50
GM17C	85/08/23	2:46	1.48	98.47
GM4B	85/08/23	2:50	1.70	99.68
GM4A	85/08/23	2:51	1.55	
GM19B	85/08/23	2:53	2.31	99.34
GM19C	85/08/23	2:54	2.20	99.79
GM13A	85/08/23	2:59	1.29	99.63
GM13B	85/08/23	3:00	1.55	99.43
GM12A	85/08/23	3:03	0.97	100.25
GM12B	85/08/23	3:04	1.07	100.23

REMARKS: LB2B to LB3C Inc. All Under Water. N4C - No Top, Measured With Original Piece in Place. GM4 - (Thermistor) Open End.

BOREHOLE – Top of Ground Well – Top of Casing (F) – Frozen

GROUNDWATER LEVEL RECORD

SITE ID: Gunnar Main FIELD REP. B. Meays PAGE 1 OF 1

LOCATION ID	LOG DATE	LOG TIME	GROUNDWATER (m) BELOW DATUM	LOCATION ELEVATION (m)
GM3B	85/08/24	9:40	2.05	100.31
GM3D	85/08/24	9:41	2.75	99.83
N2E	85/08/24	10:15	1.02	101.15
N2G	85/08/24	10:15	1.09	101.15
N2H	85/08/24	10:16	1.06	101.07
N3A	85/08/24	11:40	1.23	97.74
N3D	85/08/24	11:41	1.18	97.86
N3E	85/08/24	11:41	0.57	98.46
N3F	85/08/24	11:42	1.10	97.93
N1C	85/08/24	5:30	5.73	101.15
N6C	85/08/25	12:39	0.79	99.44
N6D	85/08/25	12:40	0.84	99.53
N6E	85/08/25	12:40	0.65	99.66
N6B	85/08/25	12:41	0.97	99.41
N6A	85/08/25	12:41	1.22	99.15
GM2B	85/08/25	1:12	3.65	100.90

REMARKS: N3D - Not Enough to Sample.

BOREHOLE - Top of Ground Well - Top of Casing (F) - Frozen

5.4.3 Response Test Data

The following sheets summarize the results of the response tests (slug testing) done during the various campaigns.

The measurements were made from the top of the pipe. The screen interval and depth of the well (drilled length) are from the top of ground surface. The measurements have been corrected for tape corrections in the same manner as the groundwater level readings.

Complete permeability calculations for hydraulic conductivity were not made as this was considered beyond the scope of this study. Some calculations were performed, however, to confirm that the data obtained was reasonable. The method used was that proposed by Hvorslev, 1951 for an isotropic soil as follows:

$$k = \frac{r^2}{2L(t_2-t_1)} \ln \frac{L}{R} \ln \frac{H_1}{H_2}$$

Where:
Ho - Static or initial depth to water - m
r - Radius of the inside of the piezometer - 0.0175 m
R - Radius of the outside of the piezometer - 0.0255 m
L - Length of the piezometer - 0.127 m
k - Coefficient of permeability (m/s)

The observations were plotted on a semilogarithmic plot with the head ratio (Ht/Ho) plotted versus the arithmetic time as the abscissa. Two typical times are chosen from the straight line portion of the plot giving a t_1, H_1 (time at point 1 and depth at point 1) and a t_2, and H_2.

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N1C

SLUG VOLUME (litres)

INITIAL WATER LEVEL (at t_0):

DATE Dec.10/84

TIME 3:17

DEPTH (m from top of casing) 7.85

STATIC WATER LEVEL

DATE Dec.10/84 TIME 3:00

DEPTH (m from top of casing) 5.88

OPEN INTERVAL (m) 9.67 to 9.80

Height Above Ground (m) 0.38

WELL DIAMETER (m) 0.035

FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1 / t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
23	6.80			
47	6.38			
75	6.08			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N1E

SLUG VOLUME (litres):

INITIAL WATER LEVEL (at t_0):

DATE 85/04/11

TIME 16:43

DEPTH (m from top of casing) 7.64

STATIC WATER LEVEL

DATE: 85/04/11 TIME: 16:38

DEPTH (m from top of casing) 6.12

OPEN INTERVAL (m) 7.79 to 7.92

Height Above Ground (m) 0.23

WELL DIAMETER (m) 0.035

FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1 / t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	7.640			
1	7.460			
2	7.390			
4	7.240			
9	7.100			
17	6.835			
32	6.500			
62	6.210			
122	6.125			
287	6.120			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID N2A

SLUG VOLUME (litres)

INITIAL WATER LEVEL (at t_0)

DATE Dec.6/84

TIME 12:51

DEPTH (m from top of casing) 4.65

STATIC WATER LEVEL

DATE Dec.6/84 TIME 12:45

DEPTH (m from top of casing) 1.66

OPEN INTERVAL (m) 4.42 to 4.55

Height Above Ground (m) 0.24

WELL DIAMETER (m) 0.035

FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/Ho or $\frac{H-h}{H-H_0}$
2	4.63			
5	4.60			
11	4.56			
19	4.49			
28	4.42			
39	4.32			
54	4.20			
74	4.08			
113	3.82			

REMARKS:

SLUG TEST DATA

SITE ID Gunnar LOCATION ID N2A

SLUG VOLUME (litres)

INITIAL WATER LEVEL (at t_0)

DATE Dec.3/84

TIME 11:30

DEPTH (m from top of casing) 3.24

STATIC WATER LEVEL

DATE Dec.6/84 TIME 12:45

DEPTH (m from top of casing) 1.66

OPEN INTERVAL (m) 4.42 to 4.55

Height Above Ground (m) 0.24

WELL DIAMETER (m) 0.035

FIELD REP

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/Ho or $\frac{H-h}{H-H_0}$
90	3.02			
185	2.80			
245	2.67			
1350	1.80			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N2R
SLUG VOLUME (litres):
INITIAL WATER LEVEL (at t_0):
DATE Dec.6/84
TIME 10:56
DEPTH (m from top of casing) 5.83

STATIC WATER LEVEL
DATE Dec.6/84 TIME 10:50
DEPTH (m from top of casing) 1.70
OPEN INTERVAL (m) 5.72 to 5.85
Height Above Ground (m) 0.28
WELL DIAMETER (m) 0.035
FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
1	5.63			
2	5.53			
3	5.40			
5	5.16			
6.5	5.03			
8	4.89			
10	4.71			
12	4.53			
14	4.37			
19	3.95			
26	3.53			
34	3.18			
48	2.64			
64	2.02			
108	1.82			
168	1.73			
231	1.71			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N2B
SLUG VOLUME (litres):
INITIAL WATER LEVEL (at t_0):
DATE Dec.3/84
TIME 11:30
DEPTH (m from top of casing) 5.48

STATIC WATER LEVEL
DATE Dec.6/84 TIME 10:50
DEPTH (m from top of casing) 1.70
OPEN INTERVAL (m) 5.72 to 5.85
Height Above Ground (m) 0.28
WELL DIAMETER (m) 0.035
FIELD REP

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
90	4.98			
185	4.29			
245	3.96			
1350	1.86			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID N2C

SLUG VOLUME (litres)

INITIAL WATER LEVEL (at t_0)

DATE Dec.3/84

TIME 11:30

DEPTH (m from top of casing) 2.58

STATIC WATER LEVEL

DATE Dec.4/84 TIME 10:00

DEPTH (m from top of casing) 2.52

OPEN INTERVAL (m) 2.33 to 2.46

Height Above Ground (m) 0.15

WELL DIAMETER (m) 0.035

FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
90	2.58			
185	2.55			
245	2.55			
1350	2.52			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID N2D

SLUG VOLUME (litres)

INITIAL WATER LEVEL (at t_0)

DATE Dec.3/84

TIME 11:30

DEPTH (m from top of casing) 1.73

STATIC WATER LEVEL

DATE Dec.6/84 TIME 10:15

DEPTH (m from top of casing) 1.48

OPEN INTERVAL (m) 1.63 to 1.76

Height Above Ground (m) 0.08

WELL DIAMETER (m) 0.035

FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
90	1.55			
185	1.49			
245	1.48			
1350	1.48			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N2D

STATIC WATER LEVEL DATE: Dec.6/84 TIME: 10:15

SLUG VOLUME (litres)

DEPTH (m from top of casing) 1.48

INITIAL WATER LEVEL (at t_0):

OPEN INTERVAL (m) 1.63 to 1.76

DATE Dec.6/84

Height Above Ground (m) 0.08

TIME 10:19:15

WELL DIAMETER (m) 0.035

DEPTH (m from top of casing) 1.81

FIELD REP. B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/Ho or $\frac{H-h}{H-H_0}$
0.75	1.80			
2.75	1.80			
4.75	1.79			
7.75	1.77			
11	1.76			
16	1.74			
26	1.70			
41	1.65			
66	1.60			
83	1.57			
100	1.55			
144	1.52			
204	1.49			
269	1.49			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N3A

STATIC WATER LEVEL DATE: Dec.7/84 TIME:

SLUG VOLUME (litres)

DEPTH (m from top of casing) 1.07 (F)

INITIAL WATER LEVEL (at t_0):

OPEN INTERVAL (m) 2.91 to 3.04

DATE Dec.4/84

Height Above Ground (m) 1.13

TIME 12:49

WELL DIAMETER (m) 0.035

DEPTH (m from top of casing) 3.74

FIELD REP. Blackport

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/Ho or $\frac{H-h}{H-H_0}$
0	3.74			
3	3.74			
14	3.73			
20	3.73			
29	3.72			
38	3.71			
53	3.68			
67	3.67			
112	3.59 *			
176	3.51			
1283	2.41			

REMARKS Recovery test from bottom of well

* New Tape

SLUG TEST DATA

SITE ID Gunnar LOCATION ID N3C
SLUG VOLUME (litres)
INITIAL WATER LEVEL (at t_0)
DATE Dec.4/84
TIME 12:03
DEPTH (m from top of casing) 3.14

STATIC WATER LEVEL
DATE Dec.4/84 TIME 13:00
DEPTH (m from top of casing) 1.46
OPEN INTERVAL (m) 2.30+ to 2.43+
Height Above Ground (m) 0.97
WELL DIAMETER (m) 0.035
FIELD REP Brinkman/Blackport

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/Ho or $\frac{H-h}{H-H_0}$
0	3.14			
1	3.13			
7	3.11			
15	3.08			
25	3.06			
39	3.02			
53	2.98			
100	2.86			
104	2.74			
1270	1.50			

REMARKS Recovery test from bottom of well
Temperature -25 to -35^{0}C

SLUG TEST DATA

SITE ID Gunnar LOCATION ID N3E
SLUG VOLUME (litres)
INITIAL WATER LEVEL (at t_0)
DATE Dec.7/84
TIME 14:48
DEPTH (m from top of casing) 12.58

STATIC WATER LEVEL
DATE Dec.8/84 TIME 10:40
DEPTH (m from top of casing) 11.25
OPEN INTERVAL (m) 13.35 to 13.48
Height Above Ground (m) 0.26
WELL DIAMETER (m) 0.035
FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/Ho or $\frac{H-h}{H-H_0}$
6	12.58			
12	12.57			
46	12.53			
1200	11.25			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N3F

SLUG VOLUME (litres)

INITIAL WATER LEVEL (at t_0)

DATE Dec.7/84

TIME 14:46

DEPTH (m from top of casing) 8.23

STATIC WATER LEVEL

DATE Dec.7/84 TIME 14:40

DEPTH (m from top of casing) 7.70

OPEN INTERVAL (m) 7.98 to 8.11

Height Above Ground (m) 0.25

WELL DIAMETER (m) 0.035

FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
7	8.23			
14	8.225			
47	8.21			
1200	7.76			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N4A

SLUG VOLUME (litres)

INITIAL WATER LEVEL (at t_0)

DATE Dec.8/84

TIME 12:50

DEPTH (m from top of casing) 5.93

STATIC WATER LEVEL

DATE Dec.8/84 TIME 11:40

DEPTH (m from top of casing) 4.92

OPEN INTERVAL (m) 5.41 to 5.54

Height Above Ground (m) 0.38

WELL DIAMETER (m) 0.035

FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
152	5.83			
1290	5.30			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N4B
SLUG VOLUME (litres)
INITIAL WATER LEVEL (at t_0):
DATE Dec.8/84
TIME 15:10
DEPTH (m from top of casing) 4.44

STATIC WATER LEVEL
DATE Dec.8/84 TIME 11:40
DEPTH (m from top of casing) 4.08
OPEN INTERVAL (m) 3.87 to 4.00
Height Above Ground (m) 0.42
WELL DIAMETER (m) 0.035
FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
13	4.44			
1140	4.21			

REMARKS:

SLUG TEST DATA

SITE ID Gunnar LOCATION ID N4C
SLUG VOLUME (litres)
INITIAL WATER LEVEL (at t_0)
DATE Dec.8/84
TIME 13:08
DEPTH (m from top of casing) 2.81

STATIC WATER LEVEL
DATE Dec.8/84 TIME 11:40
DEPTH (m from top of casing) 1.99
OPEN INTERVAL (m) 2.33 to 2.46
Height Above Ground (m) 0.36
WELL DIAMETER (m) 0.035
FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
136	2.71			
1272	2.07			

REMARKS:

SLUG TEST DATA

SITE ID Gunnae LOCATION ID· N4D

SLUG VOLUME (litres)

INITIAL WATER LEVEL (at t_0)

DATE Dec.8/84

TIME 14:28

DEPTH (m from top of casing) 1.89

STATIC WATER LEVEL

DATE Dec.9/84 TIME 10:20

DEPTH (m from top of casing) 1.65

OPEN INTERVAL (m) 1.28 to 1.41

Height Above Ground (m) 0.76

WELL DIAMETER (m) 0.035

FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/Ho or $\frac{H-h}{H-H_0}$
58	1.67			
1200	1.65			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID· N5A

SLUG VOLUME (litres)

INITIAL WATER LEVEL (at t_0)

DATE Dec.9/84

TIME 14:29

DEPTH (m from top of casing) 12.21

STATIC WATER LEVEL

DATE Dec.9/84 TIME 11:15

DEPTH (m from top of casing) 11.25

OPEN INTERVAL (m) 11.67 to 11.80

Height Above Ground (m) 0.38

WELL DIAMETER (m) 0.035

FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/Ho or $\frac{H-h}{H-H_0}$
46	12.18			
1230	11.50			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N5A
SLUG VOLUME (litres):
INITIAL WATER LEVEL (at t_0):
DATE 85/04/12
TIME: 9:58
DEPTH (m from top of casing) 5.53

STATIC WATER LEVEL
DATE: 85/04/12 TIME: 9:53
DEPTH (m from top of casing) 2.34
OPEN INTERVAL (m) 11.67 to 11.80
Height Above Ground (m) 0.38
WELL DIAMETER (m) 0.035
FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	5.530			
1	5.520			
3	5.520			
7	5.510			
17	5.500			
37	5.500			
77	5.485			
137	5.480			
257	5.450			

REMARKS:

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N5B
SLUG VOLUME (litres):
INITIAL WATER LEVEL (at t_0):
DATE 85/04/12
TIME: 10:11
DEPTH (m from top of casing) 3.625

STATIC WATER LEVEL
DATE: 85/04/12 TIME: 10:04
DEPTH (m from top of casing) 2.81
OPEN INTERVAL (m) 3.36 to 3.49
Height Above Ground (m) 0.42
WELL DIAMETER (m) 0.035
FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	3.626			
1	3.625			
3	3.625			
7	3.625			
19	3.625			
34	3.625			
94	3.620			
214	3.605			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID · N5B

SLUG VOLUME (litres)

INITIAL WATER LEVEL (at t_0)

DATE Dec.9/84

TIME 13:26

DEPTH (m from top of casing) 3.93

STATIC WATER LEVEL

DATE Dec.9/84 TIME 11:15

DEPTH (m from top of casing) 3.46

OPEN INTERVAL (m) 3.36 to 3.49

Height Above Ground (m) 0.42

WELL DIAMETER (m) 0.035

FIELD REP B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1 / t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
64	3.925			
110	3.92			
1290	3.70			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID · N5C

SLUG VOLUME (litres)

INITIAL WATER LEVEL (at t_0)

DATE Dec.9/84

TIME 12:23

DEPTH (m from top of casing) 2.59

STATIC WATER LEVEL

DATE: Dec.9/84 TIME 11:15

DEPTH (m from top of casing) 1.80

OPEN INTERVAL (m) 2.10 to 2.23

Height Above Ground (m) 0.37

WELL DIAMETER (m) 0.035

FIELD REP. B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1 / t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
23	2.57			
63	2.53			
128	2.46			
174	2.44			
1350	1.93			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM2B
SLUG VOLUME (litres)
INITIAL WATER LEVEL (at t_o):
DATE 85/04/11
TIME: 17:35
DEPTH (m from top of casing) 6.32

STATIC WATER LEVEL
DATE: 85/04/11 TIME: 17:27
DEPTH (m from top of casing) 4.09
OPEN INTERVAL (m) 6.97 to 7.10
Height Above Ground (m) 0.45
WELL DIAMETER (m) 0.035
FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_o)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1 / t_m$	H/H_o or $\frac{H-h}{H-H_o}$
0	6.320			
1	6.255			
5	6.160			
7	6.110			
10	6.020			
18	5.750			
22	5.680			
82	5.430			
102	5.040			
165	4.365			
300	4.120			

REMARKS:

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM3B
SLUG VOLUME (litres)
INITIAL WATER LEVEL (at t_o):
DATE 85/04/11
TIME 14:25
DEPTH (m from top of casing) 8.27

STATIC WATER LEVEL
DATE 85/04/11 TIME 21:15
DEPTH (m from top of casing) 6.165
OPEN INTERVAL (m) 9.90 to 10.03
Height Above Ground (m) 0.38
WELL DIAMETER (m) 0.035
FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_o)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1 / t_m$	H/H_o or $\frac{H-h}{H-H_o}$
1	8.270			
3	8.270			
5	8.270			
10	8.270			
15	8.270			
35	8.270			
59	8.260			
95	8.260			
162	8.230			
291	8.200			
429	8.170			

REMARKS:

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GM3C
SLUG VOLUME (litres):
INITIAL WATER LEVEL (at t_0):
DATE 85/04/11
TIME: 14:51
DEPTH (m from top of casing) 2.77

STATIC WATER LEVEL
DATE 85/04/11 TIME 14:40
DEPTH (m from top of casing) 2.295
OPEN INTERVAL (m) 4.14 to 4.27
Height Above Ground (m) 0.52
WELL DIAMETER (m) 0.035
FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	2.770			
1	2.740			
2	2.720			
5	2.690			
9	2.650			
17	2.590			
25	2.520			
39	2.485			
64	2.430			
136	2.350			
274	2.310			
404	2.285			

REMARKS:

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GM3D
SLUG VOLUME (litres):
INITIAL WATER LEVEL (at t_0):
DATE 85/04/11
TIME: 15:15
DEPTH (m from top of casing) 2.74

STATIC WATER LEVEL
DATE: 85/04/11 TIME: 15:04
DEPTH (m from top of casing) 2.34
OPEN INTERVAL (m) 4.28 to 4.41
Height Above Ground (m) 0.60
WELL DIAMETER (m) 0.035
FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	2.740			
1	2.570			
2	2.450			
3	2.410			
5	2.390			
9	2.375			
15	2.370			
30	2.370			
60	2.370			
120	2.350			
240	2.350			
283	2.350			

REMARKS:

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM3E

SLUG VOLUME (litres):

INITIAL WATER LEVEL (at T_0):

DATE 85/04/11

TIME: 15:43

DEPTH (m from top of casing) 2.79

STATIC WATER LEVEL

DATE: 85/04/11 TIME: 15:36

DEPTH (m from top of casing) 2.20

OPEN INTERVAL (m) 4.36 to 4.49

Height Above Ground (m) 0.50

WELL DIAMETER (m) 0.035

FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	2.790			
1	2.480			
2	2.410			
3	2.355			
5	2.245			
7	2.220			
12	2.210			
32	2.220			

REMARKS:

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM4B

SLUG VOLUME (litres):

INITIAL WATER LEVEL (at T_0):

DATE 85/03/27

TIME: 13:01

DEPTH (m from top of casing) 4.84

STATIC WATER LEVEL

DATE 85/03/27 TIME 13:00

DEPTH (m from top of casing) 1.89

OPEN INTERVAL (m) 4.67 to 4.80

Height Above Ground (m) 0.40

WELL DIAMETER (m) 0.035

FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
3	4.820			
5	4.810			
9	4.800			
17	4.780			
29	4.755			
67	4.675			
115	4.600			
183	4.490			
1263	3.220			

REMARKS:

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM9B

STATIC WATER LEVEL DATE: 85/03/27 TIME: 10:00 am

SLUG VOLUME (litres):

DEPTH (m from top of casing) 4.23

INITIAL WATER LEVEL (at t_0):

OPEN INTERVAL (m) 4.10 to 4.23

DATE 85/03/27

Height Above Ground (m) 0.37

TIME 10:05 am

WELL DIAMETER (m) 0.035

DEPTH (m from top of casing) 4.53

FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
4	4.530			
12	4.530			
27	4.525			
43	4.525			
91	4.525			
160	4.525			
178	4.520			
245	4.520			
1317	4.510			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM9C

STATIC WATER LEVEL DATE: 85/03/27 TIME: 10:11 am

SLUG VOLUME (litres):

DEPTH (m from top of casing) 2.50

INITIAL WATER LEVEL (at t_0):

OPEN INTERVAL (m) 3.54 to 3.67

DATE 85/03/27

Height Above Ground (m) 0.30

TIME: 10:15 am

WELL DIAMETER (m) 0.035

DEPTH (m from top of casing) 3.62

FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
2	3.540			
5	3.395			
10	3.240			
16	3.080			
23	2.950			
32	2.825			
82	2.540			
149	2.510			
287	2.505			
353	2.505			
1424	2.520			

REMARKS

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GM12B
SLUG VOLUME (litres):
INITIAL WATER LEVEL (at t_0):
DATE 85/03/29
TIME: 10:26 am
DEPTH (m from top of casing) 2.10

STATIC WATER LEVEL
DATE: 85/03/29 TIME:
DEPTH (m from top of casing) 1.81
OPEN INTERVAL (m) 1.77 to 1.90
Height Above Ground (m) 0.40
WELL DIAMETER (m) 0.035
FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/Ho or $\frac{H-h}{H-H_0}$
2	2.090			
6	2.090			
14	2.090			
34	2.080			

REMARKS:

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM13A
SLUG VOLUME (litres):
INITIAL WATER LEVEL (at t_0):
DATE 85/03/27
TIME: 13:53
DEPTH (m from top of casing) 6.84

STATIC WATER LEVEL
DATE: 85/03/27 TIME: 13:41
DEPTH (m from top of casing) 5.85
OPEN INTERVAL (m) 6.86 to 6.99
Height Above Ground (m) 0.32
WELL DIAMETER (m) 0.035
FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/Ho or $\frac{H-h}{H-H_0}$
2	6.835			
5	6.830			
9	6.825			
14	6.825			
23	6.820			
39	6.815			
58	6.805			
138	6.760			
1216	6.230			

REMARKS:

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GM13B
SLUG VOLUME (litres):
INITIAL WATER LEVEL (at t_0):
DATE 85/03/27
TIME: 13:57
DEPTH (m from top of casing) 3.295

STATIC WATER LEVEL
DATE 85/03/27 TIME: 13:43
DEPTH (m from top of casing) 2.18
OPEN INTERVAL (m) 3.12 to 3.25
Height Above Ground (m) 0.38
WELL DIAMETER (m) 0.035
FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
3	3.295			
6	3.290			
11	3.285			
19	3.280			
36	3.275			
55	3.270			
134	3.235			
1213	2.865			

REMARKS

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GM17B
SLUG VOLUME (litres): 800 cc ±
INITIAL WATER LEVEL (at t_0):
DATE 85/03/21
TIME: 10:00 am
DEPTH (m from top of casing) 2.59

STATIC WATER LEVEL
DATE: 85/03/21 TIME: 9:48 am
DEPTH (m from top of casing) 2.05
OPEN INTERVAL (m) 3.30 to 3.43
Height Above Ground (m) 0.34
WELL DIAMETER (m) 0.035
FIELD REP. G. Bell

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	2.59			
15	2.575			
30	2.515			
45	2.555			
60	2.54			
75	2.535			
90	2.525			
105	2.515			
120	2.505			
135	2.495			
150	2.49			
165	2.475			
180	2.465			

REMARKS. Removed about 800 cc, insert transducer to 3 m. Diameter of transducer wire - 0.8 cm.

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM17C

SLUG VOLUME (litres): 500 cc ±

INITIAL WATER LEVEL (at T_0): ~2.3

DATE 85/03/21

TIME: 13:10 pm

DEPTH (m from top of casing)

STATIC WATER LEVEL

DATE: ______ TIME: ______

DEPTH (m from top of casing) 1.51

OPEN INTERVAL (m) 1.80 to 1.93

Height Above Ground (m) 0.35

WELL DIAMETER (m) 0.035

FIELD REP. G. Bell

ELAPSED TIME (MIN. from T_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/T_m$	H/Ho or $\frac{H-h}{H-H_0}$
0	1.815			
1	1.805			
2	1.80			
4	1.775			
6	1.75			
8	1.735			
10	1.73			
12	1.715			

REMARKS: Removed 800 cc, inserted transducer to 2 m. Diameter of transducer wire - 0.8 cm.

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM19B

SLUG VOLUME (litres):

INITIAL WATER LEVEL (at T_0):

DATE 85/04/11

TIME: 18:59

DEPTH (m from top of casing) 4.08

STATIC WATER LEVEL

DATE: 85/04/11 TIME: 18:50

DEPTH (m from top of casing) 2.30

OPEN INTERVAL (m) 3.70 to 3.83

Height Above Ground (m) 0.65

WELL DIAMETER (m) 0.035

FIELD REP. S. Sponton

ELAPSED TIME (MIN. from T_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/T_m$	H/Ho or $\frac{H-h}{H-H_0}$
0	4.080			
4	3.980			
6	3.915			
10	3.840			
21	3.560			
51	3.210			
161	2.500			

REMARKS:

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GC5B
SLUG VOLUME (litres):
INITIAL WATER LEVEL (at t_o):
DATE 85/03/28
TIME: 11:31 am
DEPTH (m from top of casing) 3.37

STATIC WATER LEVEL
DATE: 85/03/28 TIME: 11:24
DEPTH (m from top of casing) 3.205
OPEN INTERVAL (m) 3.10 to 3.23
Height Above Ground (m) 0.24
WELL DIAMETER (m) 0.035
FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_o)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/Ho or $\frac{H-h}{H-H_o}$
4	3.370			
9	3.360			
15	3.360			
25	3.360			
96	3.360			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GC5C
SLUG VOLUME (litres):
INITIAL WATER LEVEL (at t_o):
DATE 85/04/12
TIME: 11:54
DEPTH (m from top of casing) 4.05

STATIC WATER LEVEL
DATE: 85/04/12 TIME: 11:49
DEPTH (m from top of casing) 2.89
OPEN INTERVAL (m) 3.81 to 3.94
Height Above Ground (m) 0.32
WELL DIAMETER (m) 0.035
FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_o)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/Ho or $\frac{H-h}{H-H_o}$
0	4.050			
1	4.050			
3	4.045			
7	4.045			
15	4.040			
36	4.040			
96	4.030			
216	4.020			

REMARKS

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GC5C

SLUG VOLUME (litres):

INITIAL WATER LEVEL (at t_0):

DATE 85 /03/28

TIME: 11:38 am

DEPTH (m from top of casing) 4.18

STATIC WATER LEVEL

DATE: 85/03/28 TIME: 11:33 am

DEPTH (m from top of casing) 3.78

OPEN INTERVAL (m) 3.81 to 3.94

Height Above Ground (m) 0.32

WELL DIAMETER (m) 0.035

FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/Ho or $\frac{H-h}{H-H_0}$
3	4.175			
8	4.170			
19	4.160			
139	4.160			

REMARKS:

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: LB2B

SLUG VOLUME (litres):

INITIAL WATER LEVEL (at t_0):

DATE 85/04/12

TIME: 10:49

DEPTH (m from top of casing) 3.645

STATIC WATER LEVEL

DATE 85/04/12 TIME 10:38

DEPTH (m from top of casing) 1.62

OPEN INTERVAL (m) 3.59 to 3.72

Height Above Ground (m) 0.35

WELL DIAMETER (m) 0.035

FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/Ho or $\frac{H-h}{H-H_0}$
0	3.645			
1	3.645			
3	3.645			
7	3.645			
17	3.645			
41	3.620			
101	3.605			
221	3.570			

REMARKS:

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: LB2B

SLUG VOLUME (litres):

INITIAL WATER LEVEL (at t_0):

DATE: 85/03/28

TIME: 13:32

DEPTH (m from top of casing): 3.72

STATIC WATER LEVEL

DATE: 85/03/28 TIME: 13:25

DEPTH (m from top of casing): 3.18

OPEN INTERVAL (m): 3.59 to 3.72

Height Above Ground (m): 0.35

WELL DIAMETER (m): 0.035

FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
4	3.710			
13	3.710			
25	3.710			
32	3.710			

REMARKS

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: LB2C

SLUG VOLUME (litres):

INITIAL WATER LEVEL (at t_0):

DATE: 85/04/12

TIME: 11:01

DEPTH (m from top of casing): 3.51

STATIC WATER LEVEL

DATE: 85/04/12 TIME: 10:41

DEPTH (m from top of casing): 1.50

OPEN INTERVAL (m): 3.38 to 3.51

Height Above Ground (m): 0.40

WELL DIAMETER (m): 0.036

FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	3.510			
1	3.505			
3	3.500			
7	3.495			
10	3.480			
34	3.465			
94	3.460			
214	3.285			

REMARKS

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: LB2C

SLUG VOLUME (litres):

INITIAL WATER LEVEL (at t_0): 3.395

DATE 85/03/28

TIME: 13:35

DEPTH (m from top of casing) 3.395

STATIC WATER LEVEL

DATE: 85/03/28 TIME: 13:23

DEPTH (m from top of casing) 1.97

OPEN INTERVAL (m) 3.38 to 3.51

Height Above Ground (m) 0.40

WELL DIAMETER (m) 0.035

FIELD REP. S. Sponton

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
9	3.390			
21	3.390			
29	3.370			

REMARKS:

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N1C

SLUG VOLUME (litres): Approx. 7.0

INITIAL WATER LEVEL (at t_0): 5.94

DATE 06/21/85

TIME: 3:15 P.M.

DEPTH (m from top of casing) 9.27

STATIC WATER LEVEL

DATE 06/21/85 TIME 3:15 P.M.

DEPTH (m from top of casing) 5.94

OPEN INTERVAL (m) 9.67 to 9.80

Height Above Ground (m) 0.38

WELL DIAMETER (m) 0.035

FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN (m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	9.27	3.33		
2	8.82	2.88		
3	8.49	2.55		
4	8.19	2.25		
5	7.99	2.05		
6	7.77	1.83		
7	7.59	1.65		
9	7.26	1.32		
14	6.71	0.77		
19	6.34	0.40		
243	5.94	0		

REMARKS: Recovery Test

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N1E
SLUG VOLUME (litres): Approx. 2
INITIAL WATER LEVEL (at t_0): 6.03
DATE 06/21/85
TIME: 12:45 P.M.
DEPTH (m from top of casing) 7.73

STATIC WATER LEVEL
DATE: 06/21/85 TIME: 12:30 P.M.
DEPTH (m from top of casing) 6.03
OPEN INTERVAL (m) 7.79 to 7.92
Height Above Ground (m) 0.23
WELL DIAMETER (m) 0.035
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/T_m$	H/H_o or $\frac{H-h}{H-H_o}$
0	7.73	1.70		
2	7.54	1.51		
4	7.34	1.31		
6	7.18	1.15		
9	6.97	0.94		
14	6.71	0.68		
116	6.03	0		

REMARKS Recovery Test

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N3A
SLUG VOLUME (litres): Approx. 2.0
INITIAL WATER LEVEL (at t_0): 0.84
DATE 06/21/85
TIME: 10:40 A.M.
DEPTH (m from top of casing) 3.20

STATIC WATER LEVEL
DATE: 06/21/85 TIME: 10:40 A.M.
DEPTH (m from top of casing) 0.84
OPEN INTERVAL (m) 2.91 to 3.04
Height Above Ground (m) 1.13
WELL DIAMETER (m) 0.035
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/T_m$	H/H_o or $\frac{H-h}{H-H_o}$
0	3.20	2.36		
1	3.19	2.35		
6	3.16	2.32		
11	3.18	2.34		
19	3.16	2.32		
27	3.15	2.31		
376	2.84	2.00		

REMARKS Recovery Test

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: N3D
SLUG VOLUME (litres): Approx. 0.4
INITIAL WATER LEVEL (at T_0): 0.81
DATE 06/21/85
TIME: 10:50 A.M.
DEPTH (m from top of casing) 1.38

STATIC WATER LEVEL
DATE: 06/21/85 TIME 10:50 A.M.
DEPTH (m from top of casing) 0.81
OPEN INTERVAL (m) 1.01 to 1.14
Height Above Ground (m) 1.03
WELL DIAMETER (m) 0.035
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/Ho or $\frac{H-h}{H-H_0}$
0	1.38	0.57		
1	1.44	0.63		
3	1.42	0.61		
10	1.31	0.50		
18	1.22	0.41		
368	0.83	0.02		

REMARKS: Recovery Test

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: N3G
SLUG VOLUME (litres): Approx. 1.5
INITIAL WATER LEVEL (at T_0): 0.81
DATE 06/21/85
TIME 10:30 a.m.
DEPTH (m from top of casing) 2.68

STATIC WATER LEVEL
DATE 06/21/85 TIME 10:30 A.M.
DEPTH (m from top of casing) 0.81
OPEN INTERVAL (m) 2.58 to 2.71
Height Above Ground (m) 0.28
WELL DIAMETER (m) 0.035
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/Ho or $\frac{H-h}{H-H_0}$
0	2.68	1.87		
3	2.53	1.72		
13	2.01	1.20		
24	1.75	0.94		
32	1.65	0.84		
40	1.52	0.71		
390	0.84	0.03		

REMARKS: Recovery Test

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: N6B
SLUG VOLUME (litres): Approx. 4.0
INITIAL WATER LEVEL (at t_0): 0.72
DATE: 06/21/85
TIME: 11:30 A.M.
DEPTH (m from top of casing): 5.49

STATIC WATER LEVEL
DATE: 06/21/85 TIME: 11:30 A.M.
DEPTH (m from top of casing): 0.72
OPEN INTERVAL (m): 5.15 to 5.23
Height Above Ground (m): 0.48
WELL DIAMETER (m): 0.35
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	5.49	4.77		
2	5.47	4.75		
10	5.45	4.73		
19	5.42	4.70		
25	5.40	4.68		
36	5.37	4.65		
283	4.79	4.07		
357	4.64	3.92		
1348	3.05	2.33		
2820	1.84	1.12		

REMARKS: Recovery Test

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: N6C
SLUG VOLUME (litres): Approx. 3.0
INITIAL WATER LEVEL (at t_0): 0.62
DATE: 06/21/85
TIME: 11:40 A.M.
DEPTH (m from top of casing): 4.12

STATIC WATER LEVEL
DATE: 06/21/85 TIME: 11:40 A.M.
DEPTH (m from top of casing): 0.62
OPEN INTERVAL (m): 3.93 to 4.06
Height Above Ground (m): 0.33
WELL DIAMETER (m): 0.035
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	4.12	3.50		
3	4.09	3.47		
9	4.04	3.42		
16	4.00	3.38		
26	3.93	3.31		
275	2.69	2.07		
1339	0.91	0.29		

REMARKS: Recovery Test

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: N6D

SLUG VOLUME (litres): Approx. 2

INITIAL WATER LEVEL (at t_0): 0.81

DATE 06/21/85

TIME: 11:50 A.M.

DEPTH (m from top of casing) 3.41

STATIC WATER LEVEL

DATE: 06/21/85 TIME: 11:50 A.M.

DEPTH (m from top of casing) 0.31

OPEN INTERVAL (m) 2.97 to 3.10

Height Above Ground (m) 0.53

WELL DIAMETER (m) 0.035

FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	t/t_m	H/H_0 or $\frac{H-h}{H-H_0}$
0	3.41	2.60		
2	3.36	2.55		
6	3.26	2.45		
16	3.07	2.26		
267	1.17	0.36		
338	1.03	0.22		
1339	0.82	0.01		

REMARKS: Recovery Test

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: N6E

SLUG VOLUME (litres): Approx. 1.2

INITIAL WATER LEVEL (at t_0): 0.73

DATE 06/21/85

TIME: 12:00 P.M.

DEPTH (m from top of casing) 2.30

STATIC WATER LEVEL

DATE: 06/21/85 TIME 12:00 P.M.

DEPTH (m from top of casing) 0.73

OPEN INTERVAL (m) 1.95 to 2.08

Height Above Ground (m) 0.50

WELL DIAMETER (m) 0.035

FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	t/t_m	H/H_0 or $\frac{H-h}{H-H_0}$
0	2.30	1.57		
2	2.28	1.55		
10	1.99	1.26		
390	0.89	0.16		
1323	0.73	0		

REMARKS: Recovery Test

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM2B
SLUG VOLUME (litres): Approx. 2.5
INITIAL WATER LEVEL (at t_0): 4.00
DATE 06/21/85
TIME: 4:00 P.M.
DEPTH (m from top of casing) 7.19

STATIC WATER LEVEL
DATE: 06/21/85 TIME: 4:00 P.M.
DEPTH (m from top of casing) 4.00
OPEN INTERVAL (m) 6.97 to 7.10
Height Above Ground (m) 0.45
WELL DIAMETER (m) 0.035
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1 / t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	7.19	3.19		
1	7.14	3.14		
2	7.08	3.08		
5.5	6.85	2.75		
7	6.78	2.78		
12	6.53	2.53		
1091	4.00	0		

REMARKS Recovery Test

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM3B
SLUG VOLUME (litres): Approx. 5.0
INITIAL WATER LEVEL (at t_0): 1.50
DATE 06/21/85
TIME: 7:00 P.M.
DEPTH (m from top of casing) 8.61

STATIC WATER LEVEL
DATE: 06/21/85 TIME: 7:00 P.M.
DEPTH (m from top of casing) 1.50
OPEN INTERVAL (m) 9.90 to 10.03
Height Above Ground (m) 0.38
WELL DIAMETER (m) 0.035
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1 / t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	8.61	7.11		
1	8.61	7.11		
4	8.60	7.10		
882	8.34	6.84		
2324	7.97	6.47		

REMARKS Recovery Test

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GM4B
SLUG VOLUME (litres): Approx. 3.0
INITIAL WATER LEVEL (at t_o): 1.46
DATE 06/21/85
TIME: 5:40 P.M.
DEPTH (m from top of casing) 5.04

STATIC WATER LEVEL
DATE: 06/21/85 TIME: 5:40 P.M.
DEPTH (m from top of casing): 1.46
OPEN INTERVAL (m) 4.67 to 4.80
Height Above Ground (m) 0.40
WELL DIAMETER (m) 0.035
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_o)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/H_o or $\frac{H-h}{H-H_o}$
0	5.04	3.58		
2	5.04	3.58		
6	5.04	3.58		
976	3.56	2.10		
2421	2.46	1.00		

REMARKS: Recovery Test

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM9C
SLUG VOLUME (litres): Approx. 1.5 l
INITIAL WATER LEVEL (at t_o): 1.93
DATE 06/21/85
TIME: 4:30 P.M.
DEPTH (m from top of casing) 3.62

STATIC WATER LEVEL
DATE: 06/21/85 TIME 4:30 P.M.
DEPTH (m from top of casing) 1.93
OPEN INTERVAL (m) 3.54 to 3.67
Height Above Ground (m) 0.30
WELL DIAMETER (m) 0.035
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_o)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	1 / t_m	H/H_o or $\frac{H-h}{H-H_o}$
0	3.62	1.69		
1	3.52	1.59		
2	3.45	1.52		
4	3.33	1.40		
7	3.15	1.22		
12	2.94	1.01		
1060	1.93	0.0		

REMARKS. Recovery Test

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GM13A
SLUG VOLUME (litres): Approx. 2.0
INITIAL WATER LEVEL (at t_0): 4.44
DATE 06/21/85
TIME: 6:30 P.M.
DEPTH (m from top of casing) 7.13

STATIC WATER LEVEL
DATE: 06/21/85 TIME: 6:30 P.M.
DEPTH (m from top of casing) 4.44
OPEN INTERVAL (m) 6.86 to 6.99
Height Above Ground (m) 0.32
WELL DIAMETER (m) 0.035
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	7.13	2.59		
9	7.12	2.58		
920	6.58	2.14		
2324	5.84	1.40		

REMARKS Recovery Test

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GM13B
SLUG VOLUME (litres): Approx. 0.8
INITIAL WATER LEVEL (at t_0): 2.34
DATE 06/21/85
TIME: 6:30 P.M.
DEPTH (m from top of casing) 3.37

STATIC WATER LEVEL
DATE: 06/21/85 TIME: 6:30 P.M.
DEPTH (m from top of casing) 2.34
OPEN INTERVAL (m) 3.12 to 3.25
Height Above Ground (m) 0.38
WELL DIAMETER (m) 0.035
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	3.37	1.03		
1	3.43	1.09		
7	3.43	1.09		
922	2.78	0.44		

REMARKS: Recovery Test

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GM17B

SLUG VOLUME (litres): Approx. 2.5 l

INITIAL WATER LEVEL (at t_0): 0.99

DATE 06/21/85

TIME: 5:00 P.M.

DEPTH (m from top of casing) 3.70

STATIC WATER LEVEL

DATE: 06/21/85 TIME: 5:00 P.M.

DEPTH (m from top of casing) 0.99

OPEN INTERVAL (m) 3.30 to 3.43

Height Above Ground (m) 0.34

WELL DIAMETER (m) 0.035

FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	3.70	2.71		
1	3.69	2.70		
3	3.68	2.69		
6.5	3.68	2.69		
13	3.67	2.68		
1031	2.90	1.91		

REMARKS: Recovery Test

SLUG TEST DATA

SITE ID: Gunnar LOCATION ID: GM17C

SLUG VOLUME (litres): Approx. 0.75

INITIAL WATER LEVEL (at t_0): 0.99

DATE 06/21/85

TIME: 5:15 P.M.

DEPTH (m from top of casing) 2.15

STATIC WATER LEVEL

DATE: 06/21/85 TIME: 5:15 P.M.

DEPTH (m from top of casing) 0.99

OPEN INTERVAL (m) 1.80 to 1.93

Height Above Ground (m) 0.35

WELL DIAMETER (m) 0.035

FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_0)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_0 or $\frac{H-h}{H-H_0}$
0	2.15	1.16		
1	2.13	1.14		
2	2.11	1.12		
4	2.06	1.07		
9	1.99	1.00		
1027	0.97	-0.02		

REMARKS: Recovery Test

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM19B
STATIC WATER LEVEL DATE: 06/21/85 TIME: 6:00 P.M.
SLUG VOLUME (litres): Approx. 2.0
DEPTH (m from top of casing) 1.94
INITIAL WATER LEVEL (at t_o): 1.94
OPEN INTERVAL (m) 3.70 to 3.83
DATE 06/21/85
Height Above Ground (m) 0.65
TIME: 6:00 P.M.
WELL DIAMETER (m) 0.035
DEPTH (m from top of casing) 4.32
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_o)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_o or $\frac{H-h}{H-H_o}$
0	4.32	2.38		
2	4.23	2.29		
4	4.14	2.20		
8	4.08	2.14		
11	3.89	1.95		
952	1.95	0.01		

REMARKS Recovery Test

SLUG TEST DATA

SITE ID Gunnar LOCATION ID: GM19C
STATIC WATER LEVEL DATE: 06/21/85 TIME: 6:00 P.M.
SLUG VOLUME (litres): Approx. 1.3
DEPTH (m from top of casing) 1.80
INITIAL WATER LEVEL (at t_o): 1.80
OPEN INTERVAL (m) 2.47 to 2.60
DATE 06/21/85
Height Above Ground (m) 0.58
TIME: 6:00 P.M.
WELL DIAMETER (m) 0.035
DEPTH (m from top of casing) 3.10
FIELD REP. J. Brinkman/B. Meays

ELAPSED TIME (MIN. from t_o)	GROUNDWATER (m from top of casing)	RESIDUAL DDN(m)	$1/t_m$	H/H_o or $\frac{H-h}{H-H_o}$
0	3.10	1.30		
1	3.08	1.28		
4	3.03	1.23		
9	2.96	1.16		
949	1.81	0.01		

REMARKS Recovery Test

5.4.4 Groundwater Quality Data

Tables 5.4 to 5.16 present the results of the chemical and radionuclide testing performed on the groundwater. The test results include duplicate and blind samples as noted for quality assurance. Also included are the results of the tritium testing.

TABLE 5.4 GUNNAR GROUNDWATER QUALITY DATA

Location		SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main
Depth from Surface		9.7 m	9.7 m	9.7 m	9.7 m	9.7 m	7.8 m	7.8 m
Parent Material		Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings
Field Code		NIC (alternate lab blind replicate)	NIC (blind field sequenced)	NIC (alternate lab blind replicate)	NIC (alternate lab blind replicate)	NIC (alternate lab blind replicate)	NIE	NIE
Date		84.12.10	84.12.10	85.03.10	85.06.20/24	85.08.24	85.03.29	85.06.20/24
Parameter								
pH:	Laboratory	7.8	-	6.9 (7.99)	6.8 (8.03)	7.4 (7.97)	7.2	7.7
	Field	6.88	-	-	-	-	-	-
Acidity ($CaCO_3$) (mg/L)		-	-	180 (201)	144 (27)	- (L 1)	16/13	11
Alkalinity ($CaCO_3$) (mg/L):	Laboratory	565/610	-	840	570 (646)	570 (563)	143	119
	Field	767	-	-	-	-	-	-
Conductivity (umhos/cm):	Laboratory	5,600	-	5,800 (5,550)	5,000	5,900/5,800 (5,760)	3,200	2,800
	Field	5,500	-	-	-	-	-	-
Total Dissolved Solids (105°C) (mg/L)		5,500	-	6,000 (5,880)	6,000 (6,400)	- (1,370)	3,200	3,300
DOC (mg/L)		680	-	14 (12)	7.5 (L 1)	8 (3)	44	1.0
DIC (mg/L)		480	-	150 (46)	110 (170)	161/151 (160)	75	21/22
Kjeldahl-N (mg/L)		-	-	1.68	2.40	-	1.02	0.40
Major Anions (mg/L):								
Bromide		L 1	-	0.1	-	0.4 (0.15)	L 0.5	L 1
Chloride		220/220	-	330 (320)	270/280 (339)	300 (313)	8.9/8.6	5.5
Fluoride		1.6	-	1.0/0.7	0.6/0.7 (0.86)	1.4 (0.86)	1.9	1.2
Sulphate		2,700	-	3,300 (3,420)	3,100/3,200 (3,430)	3,300 (3,350)	2,200/2,100	2,100
Nitrate		1	-	L 0.2	-	1.4	L 1	-
Major Cations (mg/L):								
Magnesium		550 (640)	680	720 (740)	660//640 (672)	719 (710)	290/290	250//250
Calcium		420/410 (630)	590/480	520 (530)	480//430 (516)	500/500 (409)	530/540	470//450
Iron		123 (120)	157/132	69 (59)	44/43 (34)	40 (34)	3.5	2.2
Manganese		36 (420)	37	47 (38)	41 (34)	40 (44)	7.8	8.5
Silica SiO_2		36	48	50/49 (26)	46/51 (26)	- (2.6)	22	27
Aluminum		0.29 (1.0)	0.33	0.45 (0.05)	1.1//0.81 (0.01)	0.81 (0.017)	0.58/0.58	1.1//0.76
Sodium		156/140 (130)	185/175	200 (210)	197//196 (198)	192/176 (202)	54/55	52//52*
Potassium		20/17 (17)	24/22	19.1 (14)	16//17.0 (16)	17.1/15.6 (16)	11.2/10.9	6//5.8
Trace Cations (mg/L):								
Strontium		1.80	2.4	2.5 (2.1)	2//2.7 (1.6)	2.6 (2.1)	1.53/1.54	1.4//1.47
Lead		0.20 (0.06)	0.66	0.24/0.20 (L 0.005)	0.33 (L 0.005)	0.55 (0.003)	0.17	0.27
Cobalt		0.05 (0.021)	0.14	0.11/0.10 (0.20)	0.16 (0.014)	0.24 (0.024)	0.05	0.08

TABLE 5.4 GUNNAR GROUNDWATER QUALITY DATA

Location	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main	SE Side Gunnar Main
Depth from Surface	9.7 m	9.7 m	9.7 m	9.7 m	9.7 m	7.8 m	7.8 m
Parent Material	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings
Field Code	NIC (alternate lab blind replicate)	NIC (blind field sequenced)	NIC (alternate lab blind replicate)	NIC (alternate lab blind replicate)	NIC (alternate lab blind replicate)	NIE	NIE
Date	84.12.10	84.12.10	85.03.10	85.06.20/24	85.08.24	85.03.29	85.06.20/24
Parameter							
Nickel	0.04 (0.033)	0.12	0.07/0.07 (0.034)	0.05 (0.083)	0.065 (0.024)	0.03	0.03
Zinc	0.160 (0.10)	0.200	0.170 (0.036)	0.110 (0.18)	0.090 (0.016)	0.080	0.060
Chromium	0.01 (0.035)	0.06	0.04/0.04 (0.024)	0.04 (0.072)	0.050 (0.036)	0.03	0.04
Copper	0.010 (0.003)	0.025	0.030/0.030 (0.038)	0.020 (0.009)	0.020 (0.003)	0.025	0.020
Cadmium	0.015 (L 0.001)	0.050	0.050 (0.003)	0.025 (L 0.001)	0.030 (L 0.001)	0.015	0.020
Barium	0.06 (0.12)	0.07	0.02 (0.069)	L 0.05//0.04 (0.017)	0.03 (0.012)	L 0.01/L 0.01	L 0.05//0.03
Vanadium	0.02 (0.13)	0.03	0.03 (0.11)	L 0.05//0.04 (0.09)	0.04 (0.15)	0.03/0.02	L 0.05//0.03
Titanium	0.30 (0.01)	0.36	0.32 (0.006)	- (L 0.001)	- (L 0.001)	0.41	-
Arsenic (ug/L)	64	64	72/66 (110)	-	-	10	-
Selenium (ug/L)	L 0.5	L 0.5	-	-	-	-	-
Molybdenum	0.08 (0.08)	0.09	0.08 (0.05)	0.2//0.13 (0.01)	0.14 (0.078)	0.14/0.16	0.2//0.13
Beryllium	L 0.01 (0.023)	L 0.01	L 0.01 (0.008)	L 0.05//L 0.01 (0.004)	L 0.01 (0.005)	L 0.01/L 0.01	L 0.05//L 0.01
Sum Anions	74.1 (-)	-	94.8 (100.8)	83.5	88.5 (89.8)	47.8	46.2
Sum Cations	72.8 (90.1)	(91.0)	97.9 (97.0)	90.1	92.5 (88.0)	53.5	46.5
Tritium (T.U.)	-	-	-	-	-	124	-
Radionuclides							
Uranium (ug/L)	2,300/2,600	2,600	8,000 (7,400)	8,400	8,300 (8,300)	1,950	4,500
Thorium-230 (Bq/L)	0.16/1.7	0.75	-	-	0.03 (0.04±0.01)	-	-
Radium-226 (Bq/L)	2.1/4.5	2.6	3.0 (2.44±0.12)	3.0	2.5 (1.95±0.10)	1.4	-
Lead-210 (Bq/L)	L 0.3/1.5	2.3	1.5 (2.75±0.15)	0.9	5.0 (1.1±0.1)	1.7	-
Polonium-210 (Bq/L)	0.4/0.26	1.4	0.25 (1.35±0.04)	-	-	0.02	-
Radium-228 (Bq/L)	L 0.1/0.25	L 0.1	-	-	-	-	-
Thorium-232 (Bq/L)	-	-	-	-	L 0.02	-	-
Thorium-228 (Bq/L)	-	-	-	-	L 0.02	-	-

L = Less than.
( ) Alternate lab blind replicate.
* Average value.
/ = Internal replicate, or blind replicate.
// = Acid preserved bottle analysis//wet bottle unpreserved analysis.
* Electroneutrality balances: anions on unpreserved bottles; cations on preserved bottles.

TABLE 5.5 GUNNAR GROUNDWATER QUALITY DATA

Location		Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main
Depth from Surface		4.4 m	5.7 m	1.6 m	7.6 m	7.6 m	5.4 m	3.1 m	2.2 m
Parent Material		Sand, silty, dark brown tailings	Sand, some silt, dark brown tailings	Sand, some silt, reddish brown tailings	Silt, sandy reddish brown tailings	Silt, sandy reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings
Field Code		N2A	N2B	N2D	N2E	N2E	N2G	N2H	N2I
Date		84.12.04	84.12.04	84.12.04	85.03.25	85.08.24	85.03.25	85.03.25	85.03.25
Parameter									
pH:	Laboratory	7.9	7.6	-	-	7.0	7.1	7.0	7.2
	Field	6.61	6.58	6.59	-	-	-	-	-
Acidity ($CaCO_3$) (mg/L)		-	-	-	-	-	120	130	120/110
Alkalinity ($CaCO_3$) (mg/L):	Laboratory	680	395	-	-	430	500/510	210	380
	Field	413	527	380	-	-	-	-	-
Conductivity (umhos/cm):	Laboratory	4,600	4,800	-	-	-	4,230	3,500	3,800
	Field	4,000	4,000	4,500	-	4,500/4,500	-	-	-
Total Dissolved Solids (105°C) (mg/L)		4,500	,700/4,500	-	-	-	4,300	3,700/3,700	4,200
DOC (mg/L)		1,900	60	-	-	-	23	12.5	32
DIC (mg/L)		1,300	60	-	-	-	130	50	72
Kjeldahl-N (mg/L)		-	-	-	-	-	0.90/0.65	0.42	1.12
Major Anions (mg/L):									
Bromide		1	1	-	-	0.3	0.9	L 0.5	L 0.5
Chloride		180/170	160/180	-	-	210	230	140/140	180
Fluoride		0.8	0.8	-	-	0.9	1.0	0.4	0.6
Sulphate		2,500	2,500/2,300	-	-	2,600	2,800	2,300	2,500
Nitrate		1	1	-	-	1.2/1.1	L 1	L 1	L 1
Major Cations (mg/L):									
Magnesium		430	380	570	460	530	460	330/330	440
Calcium		410/370	370	400	550	460	540	490/510	540
Iron		79	116	8.2	80	-	36	58	31
Manganese		31	25	34	20	-	21	17.3	16.8
Silica SiO_2		33	63/59	32	46/46	-	48	40	30
Aluminum		0.27	0.29	0.31	0.74	-	0.74	0.58/0.64	0.67
Sodium		147/128	115/107	200/186	134	138/139	153	117/110	141
Potassium		10.1/8.7	9.7/8.2	5.5/4.3	12.1	10.2/9.5	9.2	4.0/3.5	3.8
Trace Cations (mg/L):									
Strontium		1.53	1.74	1.47	2.1	-	2.4	1.42/1.43	1.42
Lead		0.76	0.36	0.72	0.22/0.24	-	0.27	0.18	0.19
Cobalt		0.09	0.08	0.14	0.08/0.09	-	0.13	0.07	0.07

TABLE 5.5 GUNNAR GROUNDWATER QUALITY DATA

Location	Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main	Mid-south end Gunnar Main
Depth from Surface	4.4 m	5.7 m	1.6 m	7.6 m	7.6 m	5.4 m	3.1 m	2.2 m
Parent Material	Sand, silty dark brown tailings	Sand, some silt, dark brown tailings	Sand, some silt, reddish brown tailings	Silt, sandy reddish brown tailings	Silt, sandy reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings
Field Code	N2A	N2B	N2D	N2E	N2E	N2G	N2H	N2I
Date	84.12.04	84.12.04	84.12.04	85.03.25	85.08.24	85.03.25	85.03.25	85.03.25
Parameter								
Nickel	0.05	0.05	0.07	0.07/0.06	-	0.06	0.04	0.05
Zinc	0.175	0.010	0.145	0.235/0.230	-	0.110	0.080	0.100
Chromium	0.02	0.04	0.06	0.04/0.04	-	0.04	0.03	0.03
Copper	0.015	0.010	0.025	0.055/0.050	-	0.025	0.025	0.020
Cadmium	0.035	0.035	0.035	0.035/0.050	-	0.035	0.040	0.025
Barium	0.06	0.05	0.04	L 0.01	-	L 0.01	L 0.01/L 0.01	L 0.01
Vanadium	0.02	0.02	0.02	0.04	-	0.03	0.02/0.03	0.03
Titanium	0.27	0.32	0.32	0.41	-	0.42	0.38/0.44	0.42
Arsenic (ug/L)	45	78	33/40	44	-	96	96	16/15
Selenium (ug/L)	L 0.5	L 0.5	L 0.5	-	-	-	-	-
Molybdenum	0.08	0.05	0.06	0.14	-	0.14	0.10/0.08	0.15
Beryllium	L 0.01	L 0.01	L 0.01	L 0.01	-	L 0.01	L 0.01/L 0.01	L 0.01
Sum Anions	70.5	62.6	-	-	68.6	74.8	55.9	64.7
Sum Cations	61.1	54.8	(75.3)	(71.4)	72.8	74.0	59.8	72.4
Tritium (T.U.)	-	-	-	-	-	-	-	-
Radionuclides								
Uranium (ug/L)	2,600	450	-	-	2,400	1,170	2,150	3,000
Thorium-230 (Bq/L)	L 0.02	0.02	-	-	L 0.02	-	-	-
Radium-226 (Bq/L)	1.7	2.5	-	-	0.70	1.6	1.1	1.1
Lead-210 (Bq/L)	2.0	0.60	-	-	0.18	0.50	0.90	0.80
Polonium-210 (Bq/L)	0.12	0.04	-	-	-	0.06	0.05	0.11
Radium-228 (Bq/L)	L 0.10	L 0.05	-	-	-	-	-	-
Thorium-232 (Bq/L)	-	-	-	-	L 0.02	-	-	-
Thorium-228 (Bq/L)	-	-	-	-	L 0.02	-	-	-

L = Less than.

TABLE 5.6 GUNNAR GROUNDWATER QUALITY DATA

Location		Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main
Depth from Surface		2.9 m	2.9 m	2.3 m	1.0 m	1.0 m	E - 13.4 m; F - 8.0 m	E - 13.4 m	F - 8.0 m
Parent Material		Sand, some silt, reddish brown tailings	Sand, some silt, reddish brown tailings	Sand, some silt, reddish brown tailings	Sand, some silt, reddish brown tailings	Sand, some silt, reddish brown tailings	Clay, medium plastic, light grey	Clay, medium plastic, light grey	Clay, medium plastic, light grey
Field Code		N3A	N3A	N3C	N3D	N3D	N3E & F	N3E	N3F
Date		84.12.03	85.06.20/24	84.12.03	84.12.03	85.06.20/24	84.12.07	85.08.24	85.08.24
Parameter									
pH:	Laboratory	4.1	5.5	4.1	4.1	5.6	7.9	8.0	7.8
	Field	5.47	-	5.49	5.95	-	6.67	-	-
Acidity ($CaCO_3$) (mg/L)		1,060	1,050	1,040	770/800	650	-	-	-
Alkalinity ($CaCO_3$) (mg/L):	Laboratory	-	44	-	-	29	360	420	490/500
	Field	171	-	179	493	-	444	-	-
Conductivity (umhos/cm):	Laboratory	8,500	7,000	9,000	8,800	7,400	2,800	1,190	1,330
	Field	7,025/6,500	-	8,000	7,500	-	3,100	-	-
Total Dissolved Solids (105°C) (mg/L)		9,300	9,500	10,100	9,800	10,300	2,400/2,400	-	-
DOC (mg/L)		140	50	240	190	17.5	2,800/2,700	300	208
DIC (mg/L)		100	16.5	40	70	7.0	88	95/131	124/87
Kjeldahl-N (mg/L)		-	5.8	-	-	6.7	-	-	-
Major Anions (mg/L):									
Bromide		1	-	1	-	-	1/1	1.6	1.1
Chloride		510/530	480	530/540	-	500	100/100	100	46/56
Fluoride		1.2	1.3	1.2	-	0.3	0.4/0.4	0.3	0.2
Sulphate		4,900	5,300	5,600	-	5,400	1,300/1,300	115	200/190
Nitrate		1	-	1	-	-	2/1	2.3/2.1	0.54
Major Cations (mg/L):									
Magnesium		780	870//800	980	1,010	1,010//990	132/107	69	87/86
Calcium		400/350	390//360	400/360	450/360	430//410	420/320	136	200/230
Iron		720	660	890	800	490	12.7	-	-
Manganese		41	40	54	51	37	4.4	-	-
Silica SiO_2		53	45	51		26	28	-	-
Aluminum		0.51	1.2//0.95	0.47	0.45	1.0//0.60	0.28	-	-
Sodium		290/260	340//320	300/290	330/300	350//350	50/48	39	29/28
Potassium		25/21	21//20	18.4/16.0	19.0/15.4	14//15.5	10.0/7.1	7.6	8.8/8.4
Trace Cations (mg/L):									
Strontium		1.91	2//2.1	2.6	1.65	1.6//1.68	1.33	-	-
Lead		0.16	0.42	0.64	0.44	0.38	1.08	-	-
Cobalt		0.03	0.09	0.22	0.06	0.08	0.08	-	-

TABLE 5.6 GUNNAR GROUNDWATER QUALITY DATA

Location	Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main	Outlet Gunnar Main
Depth from Surface	2.9 m	2.9 m	2.3 m	1.0 m	1.0 m	E - 13.4 m; F - 8.0 m	E - 13.4 m	F - 8.0 m
Parent Material	Sand, some silt, reddish brown tailings	Sand, some silt, reddish brown tailings	Sand, some silt, reddish brown tailings	Sand, some silt, reddish brown tailings	Sand, some silt, reddish brown tailings	Clay, medium plastic, light grey	Clay, medium plastic, light grey	Clay, medium plastic, light grey
Field Code	N3A	N3A	N3C	N3D	N3D	N3E & F	N3E	N3F
Date	84.12.03	85.06.20/24	84.12.03	84.12.03	85.06.20/24	84.12.07	85.08.24	85.08.24
Parameter								
Nickel	0.03	0.09	0.43	0.03	0.05	0.08	-	-
Zinc	0.010	0.165	0.175	0.170	0.150	0.075	-	-
Chromium	0.01	0.04	0.03	0.04	0.04	0.05	-	-
Copper	0.005	0.020	0.015	0.020	0.025	0.010	-	-
Cadmium	0.105	0.140	0.130	0.12	0.120	0.020	-	-
Barium	0.04	L 0.05//0.03	0.05	0.04	L 0.05//0.03	0.15	-	-
Vanadium	0.04	L 0.05//0.04	0.03	0.04	0.05//0.04	0.02	-	-
Titanium	0.25	-	0.26	0.29	-	0.27	-	-
Arsenic (ug/L)	16	-	42	62	-	7	-	-
Selenium (ug/L)	L 0.5	-	0.5	L 0.5	-	L 0.5	-	-
Molybdenum	0.08	0.2//0.14	0.08	0.09	0.2//0.14	0.07	-	-
Beryllium	L 0.01	L 0.05//L 0.01	L 0.01	L 0.01	L 0.05//L 0.01	L 0.01	-	-
Sum Anions	116.6	124.6	131.6	-	127.0	37.1	13.6	15.4
Sum Cations	116.6	127.3	133.6	133.1	132.9	30.7	14.3	19.3
Tritium (T.U.)	-	-	-	-	-	-	-	-
Radionuclides								
Uranium (ug/L)	43±3	24±3	92±14	120	300	200	36±2	27±2
Thorium-230 (Bq/L)	0.80	-	0.55	0.09	-	L 0.1	L 0.02	L 0.02
Radium-226 (Bq/L)	7.5	-	7.0	1.2	-	3.0	4.5	3.0
Lead-210 (Bq/L)	3.0	-	6.5	1.0	-	L 0.3	L 0.04	L 0.04
Polonium-210 (Bq/L)	0.3	-	1.9	0.15	-	0.07	-	-
Radium-228 (Bq/L)	L 0.16	-	L 0.65	L 0.20	-	L 0.5	-	-
Thorium-232 (Bq/L)	-	-	-	-	-	-	L 0.02	L 0.02
Thorium-228 (Bq/L)	-	-	-	-	-	-	L 0.02	L 0.02

L = Less than.

TABLE 5.7 GUNNAR GROUNDWATER QUALITY DATA

Location	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main
Depth from Surface	11.0 m	5.2 m	5.2 m	3.9 m	3.9 m	3.0 m	3.0 m	2.0 m	2.0 m
Parent Material	Clay, medium plastic, grey	Silt, sandy reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings
Field Code	N6A	N6B	N6B	N6C	N6C	N6D	N6D	N6E	N6E
Date	85.03.12	85.03.12	85.06.20/24	85.03.12	85.06.20/24	85.03.12	85.06.20/24	85.03.12	85.06.20/24
Parameter									
pH	7.7	5.9	6.0	5.1	5.2	4.9	5.5	5.9	5.9
Acidity ($CaCO_3$) (mg/L)	37	400	310	920	790	890	680	220	230
Alkalinity ($CaCO_3$) (mg/L)	410	63	68	28	9	4	23	67/68	52
Conductivity (umhos/cm)	2,180	4,000	4,000	5,800	5,500	5,350	6,000	4,900	4,500
Total Dissolved Solids (105°C) (mg/L)	1,880/1,920	4,800	4,800	7,700	7,600	7,100	6,800	6,000	5,500/5,600
DOC (mg/L)	171	64	27/30	32	16.5/18.5	29/29	16.0	43/44	10.0
DIC (mg/L)	55	25	24	30	14.0	30	6.0	29	24
Kjeldahl-N (mg/L)	1.43	19.8	1.28	14.0	1.95	8.2	3.3	13.5/10.6	1.71
Major Anions (mg/L):									
Bromide	0.2/0.4	0.1	-	0.3	-	0.4	-	0.3	-
Chloride	17/15	140/150	128	220/220	175	210/200	180	140/150	170/160
Fluoride	0.3/0.3	0.3/0.2	0.3	0.3	0.5	0.1	L 0.3	0.2	L 0.2/0.2
Sulphate	1,000	2,800/3,000	2,900	5,400	4,600	4,400	4,100	3,100	3,500
Nitrate	L 0.2	L 0.5	-	L 1	-	L 1	-	L 1	-
Major Cations (mg/L):									
Magnesium	63	440	400//390	820	690//670	780	660//640	590/570	500//480
Calcium	520	470	460//410	420	390//340	420	400//360	460/480	480//420
Iron	7.2	260	220	520	450	430	370	240	200
Manganese	3.3	18.3	17.9/16	26/24	22	26	23	23	21
Silica SiO_2	21	65	53	55	40	47	39	48/48	42/42
Aluminum	0.53	0.65	1.0//0.56	0.62	0.8//0.53	0.52	0.9//0.52	0.56/0.73	1.1//0.60
Sodium	30	94	100//95	142	136//138	149	143//148	132/125	126//129
Potassium	6.3	10.6	18//8.9	10.8	9//9.2	12.0	10//10.5	8.9/8.1	7//7.9
Trace Cations (mg/L):									
Strontium	1.23	1.23	1.2//1.20	1.11	1.0//1.04	1.81	1.6//1.68	1.71/1.72	1.6//1.64
Lead	0.14	0.42/0.21	0.25	0.48/0.28	0.27	0.29	0.30/0.3	0.23	0.26
Cobalt	0.03	0.09/0.05	0.06	0.13/0.11	0.11	0.11	0.11	0.11	0.12

TABLE 5.7 GUNNAR GROUNDWATER QUALITY DATA

Location	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main
Depth from Surface	11.0 m	5.2 m	5.2 m	3.9 m	3.9 m	3.0 m	3.0 m	2.0 m	2.0 m
Parent Material	Clay, medium plastic, grey	Silt, sandy reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings
Field Code	N6A	N6B	N6B	N6C	N6C	N6D	N6D	N6E	N6E
Date	85.03.12	85.03.12	85.06.20/24	85.03.12	85.06.20/24	85.03.12	85.06.20/24	85.03.12	85.06.20/24
Parameter									
Nickel	0.04	0.07/0.05	0.04	0.12/0.10	0.11	0.12	0.12	0.11	0.09
Zinc	0.065	0.230/0.135	0.105	0.260/0.155	0.145	0.175	0.145	0.155	0.100
Chromium	0.03	0.07/0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03
Copper	0.010	0.030/0.020	0.020	0.020/0.020	0.020	0.025	0.020	0.030	0.015
Cadmium	0.020	0.080	0.065	0.180/0.180	0.110	0.150	0.095	0.095	0.055
Barium	L 0.01	L 0.01	L 0.05//0.02	L 0.01	L 0.05//0.02	L 0.01	L 0.05//0.03	L 0.01/L 0.01	L 0.05//0.03
Vanadium	0.03	0.03	L 0.02//0.03	0.04	L 0.05//0.03	0.03	L 0.05//0.03	0.02/0.03	L 0.05//0.03
Titanium	0.30	0.30/0.45	-	0.29	-	0.39/0.37	-	0.30	-
Arsenic (ug/L)	10	28	-	24	-	138	-	136	-
Selenium (ug/L)	-	-	-	-	-	-	-	-	-
Molybdenum	0.13	0.15	0.2//0.10	0.17	0.2//0.11	0.13	0.2//0.11	0.12/0.15	0.2//0.10
Beryllium	L 0.01	L 0.01	L 0.05//L 0.01	L 0.01	L 0.05//L 0.01	L 0.01	L 0.05//L 0.01	L 0.01/0.01	L 0.05//L 0.01
Sum Anions	29.9	67.9	65.3	119	100.8	97.5	90.8	70.1	78.6
Sum Cations	33.3	72.0	66.8	113	98.1	109.7	94.3	79.8	75.3
Tritium (T.U.)	10	22	-	-	-	-	-	L 8	-
Radionuclides									
Uranium (ug/L)	148±10 240**	22±1 -	250 47±2**	27±3 -	L 5 27±2**	142±6 -	40 290**	- -	1,300 1,200**
Thorium-230 (Bq/L)	-	-	-	-	-	-	-	-	-
Radium-226 (Bq/L)	0.8	1.8	1.8	2.5	2.5	2.5	3.0	-	3.0
Lead-210 (Bq/L)	L 0.1	2.5	1.5	3.0	0.7	3.5	1.0	-	2.0
Polonium-210 (Bq/L)	0.20	0.11	-	0.04	-	0.90	-	-	-
Radium-228 (Bq/L)	-	-	-	-	-	-	-	-	-

L = Less than.

** Sampled August 1985.

TABLE 5.8 GUNNAR GROUNDWATER QUALITY DATA

Location		Gunnar Central	Gunnar Central	Gunnar Central	Gunnar Central	Gunnar Central	Gunnar Central	Gunnar Central
Depth from Surface		5.4 m	5.4 m	3.9 m	3.9 m	2.3 m	1.3 m	1.3 m
Parent Material		Clay, low plastic, light grey	Clay, low plastic, light grey	Clay, low plastic, light grey	Clay, low plastic, light grey	Silt, sandy reddish brown tailings	Silt, sandy reddish brown tailings	Silt, sandy reddish brown tailings
Field Code		N4A	N4A	N4B	N4B	N4C	N4D	N4D
Date		84.12.08	85.08.23	84.12.08	85.08.23	84.12.08	84.12.08	85.06.20/24
Parameter								
pH:	Laboratory	7.8	7.7	-	7.4	4.9	3.9	3.6
	Field	6.37	-	5.03	-	5.94	4.88	-
Acidity ($CaCO_3$) (mg/L)		-	-	-	-	400/410	1,200	-
Alkalinity ($CaCO_3$) (mg/L):	Laboratory	143/146	350/360	-	158/165	3.5	-	3,200
	Field	246	-	99	-	185	28	-
Conductivity (umhos/cm):	Laboratory	2,300	1,890/1,860	-	1,700/1,680	4,300	14,000	25,000
	Field	-	-	-	-	4,600	11,900	-
Total Dissolved Solids (105°C) (mg/L)		2,300	-	-	-	4,700	18,300	51,000/54,000
DOC (mg/L)		1,000	-	-	-	320	360	15.3
DIC (mg/L)		600	81	-	-	200	60	L 0.5
Kjeldahl-N (mg/L)		-	-	-	-	-	-	4.5
Major Anions (mg/L):								
Bromide		1	0.15	-	L 0.2	1	10	-
Chloride		22/25	7.0/6.3	-	10	170/150	670/660	1,680
Fluoride		0.4	0.2/0.3	-	0.11	0.7	2.5/2.4	L 2
Sulphate		1,240	810	-	860	2,700	10,700	28,000
Nitrate		1	1.2/0.93	-	0.66	1	10	-
Major Cations (mg/L):								
Magnesium		112	65/64	430	47	300	2,240	6,500//6,300
Calcium		380	340/330	400/310	320	420	390/340	400//400*
Iron		47	-	167	-	360	870	1,330
Manganese		6.0	-	23/20	-	19/17	115	250
Silica SiO_2		23	-	-	-	53	74/72	46/48
Aluminum		0.26	-	1.46	-	0.37	16.2/16.0	50//53*
Sodium		30	27/25	91/75	10.1	104/94	440/350	1,310//1,320
Potassium		9.2	6.7/6.2	11.7/8.3	4.0	14.0/13.1	8.9/18.7	1.6//1.9
Trace Cations (mg/L):								
Strontium		0.84	-	0.96	-	0.89	1.81	3//3
Lead		0.82	-	0.66	-	0.48	1.88	1.4
Cobalt		0.07	-	0.11	-	0.07	0.66	1.9

TABLE 5.8 GUNNAR GROUNDWATER QUALITY DATA

Location	Gunnar Central	Gunnar Central	Gunnar Central	Gunnar Central	Gunnar Central	Gunnar Central	Gunnar Central
Depth from Surface	5.4 m	5.4 m	3.9 m	3.9 m	2.3 m	1.3 m	1.3 m
Parent Material	Clay, low plastic, light grey	Clay, low plastic, light grey	Clay, low plastic, light grey	Clay, low plastic, light grey	Silt, sandy reddish brown tailings	Silt, sandy reddish brown tailings	Silt, sandy reddish brown tailings
Field Code	N4A	N4A	N4B	N4B	N4C	N4D	N4D
Date	84.12.08	85.08.23	84.12.08	85.08.23	84.12.08	84.12.08	85.06.20/24
Parameter							
Nickel	0.07	-	0.16	-	0.06	0.92	2.9
Zinc	0.075	-	0.28	-	0.090	0.59	1.7
Chromium	0.05	-	0.03	-	0.04	0.13	0.1
Copper	0.020	-	0.025	-	0.015	0.095	0.55
Cadmium	0.030	-	0.040	-	0.070	0.155	0.35
Barium	0.07	-	0.06	-	0.05	0.07	0.1//0.10
Vanadium	0.02	-	0.03	-	0.03	0.05	0.1//0.10
Titanium	0.25	-	-	-	0.26	0.35	-
Arsenic (ug/L)	11/8	-	28	-	20	42	-
Selenium (ug/L)	L 0.5	-	L 0.5	-	L 0.5	1.0	-
Molybdenum	0.06	-	0.07	-	0.07	0.10	0.4//0.4
Beryllium	L 0.01	-	L 0.01	-	L 0.01	0.01	L 0.05//L 0.05
Sum Anions	29.3	23.8	-	21.4	60.7	241	630
Sum Cations	29.7	23.4	(56.9)	20.4	58.4	244	675
Tritium (T.U.)	-	-	-	-	-	-	-
Radionuclides							
Uranium (ug/L)	-	180	-	220	-	-	-
Thorium-230 (Bq/L)	-	L 0.02	-	L 0.04	-	-	-
Radium-226 (Bq/L)	-	0.55	-	1.2	-	-	-
Lead-210 (Bq/L)	-	L 0.04	-	0.05	-	-	-
Polonium-210 (Bq/L)	-	-	-	-	-	-	-
Radium-228 (Bq/L)	-	-	-	-	-	-	-
Thorium-232 (Bq/L)	-	L 0.02	-	L 0.02	-	-	-
Thorium-228 (Bq/L)	-	L 0.02	-	L 0.02	-	-	-

L : Less than.

* Average value.

TABLE 5.9 GUNNAR GROUNDWATER QUALITY DATA

Location		Langley Bay	Langley Bay	Langley Bay	Langley Bay	Langley Bay	Langley Bay	Langley Bay	Langley Bay
Depth from Surface		11.7 m	11.7 m	11.7 m	3.4 m	3.4 m	3.4 m	2.1 m	2.1 m
Parent Material		Clay, medium plastic, light grey	Clay, medium plastic, light grey	Clay, medium plastic, light grey	Silt, reddish brown tailings organic	Silt, reddish brown tailings, organic	Silt, reddish brown tailings, organic	Silt, reddish brown tailings	Silt, reddish brown tailings
Field Code		N5A	N5A	N5A (alternate lab blind replicate)	N5B	N5B	N5B	N5C	N5C
Date		84.12.09	85.03.09	85.06.20/24	84.12.09	85.06.20/24	85.08.23	84.12.09	85.06.20/24
Parameter									
pH:	Laboratory	7.1	7.6	7.8 (8.28)	-	6.2	4.9	4.1	4.1
	Field	6.5	-	-	5.95	-	-	6.18	-
Acidity ($CaCO_3$) (mg/L)		-	21	10	-	420/420	360	770	1,450
Alkalinity ($CaCO_3$) (mg/L):	Laboratory	15	200	180/190 (217)	-	26	L 1	-	-
	Field	178	-	-	133	-	-	166	-
Conductivity (umhos/cm):	Laboratory	2,900	780	600	-	3,100	3,600/3,500	5,000	3,100
	Field	3,000	-	-	-	-	-	5,000	-
Total Dissolved Solids (105°C) (mg/L)		2,800	550	330 (440)	-	3,900	-	5,500	3,900
DOC (mg/L)		1,500	37/31	11.0 (23)	-	26	-	1,160	48
DIC (mg/L)		1,100	30	34 (49)	-	14	-	240	13.0
Kjeldahl-N (mg/L)			1.32	1.26	-	2.4	-	-	1.44
Major Anions (mg/L):									
Bromide		1	0.3	0.3/0.3 (0.05)	-	-	1.0	1	-
Chloride		36/37	19	18 (25)	-	99	115/105	140/140	210
Fluoride		0.8	0.4	0.3/0.3 (0.47)	-	0.3	0.3	0.8	0.6
Sulphate		1,600	210	115/116 (110)	-	2,200	2,300	3,100	4,700
Nitrate		1	0.2	L 0.2	-	-	2.4/2.5	1	-
Major Cations (mg/L):									
Magnesium		162/124	18.3	28//30 (35)	200	185//185	201/201	330	580//540
Calcium		460/350	125	69//69 (74)	300/230	460//440	460	460/320	390//340
Iron		117	0.06/0.06	0.03 (0.30)	380	360	-	590	680
Manganese		10.8	0.67/0.67	0.87 (1.1)	15/12	13.2/13	-	20/16	21
Silica SiO_2		42/42	25	26 (2.6)	38	39	-	32	41
Aluminum		0.35	0.13	0.16//0.15 (0.008)	0.26	1.2//0.59	-	0.30	5//1.7
Sodium		44/45	21	23//23 (24)	61/62	108//95	12.9/12.5	77/87	164//172*
Potassium		9.2/6.4	7.4	3.8//3.8 (3.5)	6.4/5.0	13//13.1	86/83	5.2/4.2	6//7.2
Trace Cations (mg/L):									
Strontium		1.42	0.45	0.42//0.44 (0.31)	0.61	0.7//0.68	-	0.86	1.2//1.24
Lead		1.16	0.06/0.06	0.01 (L 0.005)	1.24	0.30	-	0.08	1.11/1.1
Cobalt		0.11	0.01/0.01	L 0.01 (0.001)	0.16	0.06	-	0.01	0.09

TABLE 5.9 GUNNAR GROUNDWATER QUALITY DATA

Location	Langley Bay	Langley Bay	Langley Bay	Langley Bay	Langley Bay	Langley Bay	Langley Bay	Langley Bay
Depth from Surface	11.7 m	11.7 m	11.7 m	3.4 m	3.4 m	3.4 m	2.1 m	2.1 m
Parent Material	Clay, medium plastic, light grey	Clay, medium plastic, light grey	Clay, medium plastic, light grey	Silt, reddish brown tailings organic	Silt, reddish brown tailings, organic	Silt, reddish brown tailings, organic	Silt, reddish brown tailings	Silt, reddish brown tailings
Field Code	N5A	N5A	N5A (alternate lab blind replicate)	N5B	N5B	N5B	N5C	N5C
Date	84.12.09	85.03.09	85.06.20/24	84.12.09	85.06.20/24	85.08.23	84.12.09	85.06.20/24
Parameter								
Nickel	0.13	0.06/0.05	0.01 (0.011)	0.15	0.05	-	0.03	0.08
Zinc	0.110	0.055/0.045	0.015 (0.014)	0.170	0.070	-	0.150	0.185
Chromium	0.08	0.02/0.01	L 0.01 (L 0.001)	0.09	0.04	-	0.02	0.03
Copper	0.025	0.020/0.015	0.005 (0.020)	0.025	0.015	-	0.010	0.125
Cadmium	0.055	L 0.005/0.015	0.01 (L 0.001)	0.095	0.085	-	0.115	0.165
Barium	0.07	0.05	0.08//0.08 (0.073)	0.04	L 0.05//0.02	-	0.04	L 0.05//0.03
Vanadium	0.02	0.01	L 0.01//L 0.01 (0.01)	0.02	0.05//0.03	-	0.03	L 0.05//0.04
Titanium	0.29	0.5/0.14	- (L 0.001)	0.22	-	-	0.27	-
Arsenic (ug/L)	33	12	-	40/56	-	-	18	-
Selenium (ug/L)	L 0.5	-	-	0.5	-	-	L 0.5	-
Molybdenum	0.06	0.02	0.03//0.03 (0.006)	0.07	0.2//0.11	-	0.10	0.2//0.17
Beryllium	L 0.01	L 0.01	L 0.01//L 0.01 (L 0.001)	L 0.01	L 0.05//L 0.01	-	L 0.01	L 0.05//L 0.01
Sum Anions	34.6	8.91	6.60 (7.33)	-	49.1	50.9	68.4	103.7
Sum Cations	34.1	9.26	7.04 (7.70)	(32.5)	51.6	50.7	65.7	103.3
Tritium (T.U.)	-	-	-	-	-	-	-	-
Radionuclides								
Uranium (ug/L)	220	24±1	25±4	-	17±4	25±2	-	-
Thorium-230 (Bq/L)	L 0.2	-	-	-	-	L 0.04	-	-
Radium-226 (Bq/L)	0.45	1.1	1.2	-	0.90	0.70	-	-
Lead-210 (Bq/L)	L 0.4	L 0.1	L 0.02	-	0.07	L 0.08	-	-
Polonium-210 (Bq/L)	0.19	0.03	-	-	-	-	-	-
Radium-228 (Bq/L)	L 0.8	-	-	-	-	-	-	-
Thorium-232 (Bq/L)	-	-	-	-	-	L 0.04	-	-
Thorium-228 (Bq/L)	-	-	-	-	-	L 0.04	-	-

L : Less than.

* Average value.

TABLE 5.10 GUNNAR GROUNDWATER QUALITY DATA

Location	Langley Bay	Langley Bay	Langley Bay	Langley Bay	
Depth from Surface	3.6 m	3.4 m	3.6 m	4.1 m	
Parent Material	Organic clay, greenish colour	Silt, reddish brown tailings	Organic clay, greenish colour	Clay, medium plastic, grey	
Field Code	LB2B	LB2C	LB3C	LB7B	Field Blank
Date	85.03.26	85.03.26	85.03.28	85.03.28	85.03.22
Parameter					
pH	-	6.3	-	-	6.8
Acidity ($CaCO_3$) (mg/L)	-	540	-	-	5/5
Alkalinity ($CaCO_3$) (mg/L)	-	150/130	-	-	9
Conductivity (umhos/cm)	-	3,100	-	-	21/22
Total Dissolved Solids (105°C) (mg/L)	-	3,400	-	-	L 1
DOC (mg/L)	-	56	-	-	4.0
DIC (mg/L)	-	52	-	-	L 0.5
Kjeldahl-N (mg/L)	22.2/17.1	-	-	-	0.32
Major Anions (mg/L):					
Bromide	-	1	-	-	L 0.1
Chloride	-	70/77	-	-	0.4
Fluoride	-	0.6	-	-	0.1
Sulphate	-	2,000/2,100	-	-	3.2
Nitrate	-	L 1	-	-	L 1
Major Cations (mg/L):					
Magnesium	110	136	127	55	0.27
Calcium	560	550	560	600	0.41
Iron	230	310	173	3.1/3.1	0.19/0.13
Manganese	6.4/6.6	7.4/8.2	11.3/12.9	5.6/5.5	0.02/0.01
Silica SiO_2	52	67	47	28	1.2
Aluminum	0.74	0.58	0.61	0.61	L 0.01
Sodium	53	64	48	37	1.91
Potassium	17.4	12.0	10.1	7.6	0.42
Trace Cations (mg/L):					
Strontium	0.97	1.01	1.30	1.36	L 0.01
Lead	0.18	0.23	0.24	0.16/0.15	0.01
Cobalt	0.04	0.05	0.05	0.03/0.03	L 0.01

TABLE 5.10 GUNNAR GROUNDWATER QUALITY DATA

Location	Langley Bay	Langley Bay	Langley Bay	Langley Bay	
Depth from Surface	3.6 m	3.4 m	3.6 m	4.1 m	
Parent Material	Organic clay, greenish colour	Silt, reddish brown tailings	Organic clay, greenish colour	Clay, medium plastic, grey	
Field Code	LB2B	LB2C	LB3C	LB7B	Field Blank
Date	85.03.26	85.03.26	85.03.28	85.03.28	85.03.22
Parameter					
Nickel	0.06	0.04	0.07	0.04/0.04	L 0.01
Zinc	0.155	0.105	0.170	0.060/0.050	L 0.005
Chromium	0.03	0.04	0.04	0.03/0.03	L 0.01
Copper	0.025	0.015	0.035	0.025/0.020	L 0.005
Cadmium	0.085	0.125	0.080	0.020/0.005	L 0.005
Barium	L 0.01	L 0.01	L 0.01	0.02	L 0.01
Vanadium	0.03	0.03	0.04	0.03	L 0.01
Titanium	0.39	0.41	0.44	0.43	L 0.01
Arsenic (ug/L)	28	66/70	9.0	5.5/6.5	1.5/0.5
Selenium (ug/L)	-	-	-	-	-
Molybdenum	0.15	0.14	0.14	0.14	L 0.01
Beryllium	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01
Sum Anions	-	48.9	-	-	0.26
Sum Cations	(39.7)	52.5	(40.7)	(35.7)	0.24
Tritium (T.U.)	-	L 8	L 8	-	-
Radionuclides					
Uranium (ug/L)	-	-	-	-	0.8±0.2
Thorium-230 (Bq/L)	-	-	-	-	-
Radium-226 (Bq/L)	-	-	-	-	L 0.01
Lead-210 (Bq/L)	-	-	-	-	L 0.05
Polonium-210 (Bq/L)	-	-	-	-	0.01

L = Less than.

TABLE 5.11 GUNNAR GROUNDWATER QUALITY DATA

Location	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main
Depth from Surface	Field Blank	Field Blank	7.0 m	7.0 m	9.9 m	9.9 m	9.9 m	4.1 m	4.5 m	4.4 m
Parent Material	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Silt, very sandy, reddish brown tailings	Silt, very sandy, reddish brown tailings	Silt, very sandy, reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings
Field Code	GM1C	GM1C	GM2B	GM2B	GM3B	GM3B (filtered material on mg/L basis)	GM3B	GM3C (alternate lab blind replicate)	GM3D	GM3E
Date	85.06.20/24	85.08.25	85.03.30	85.06.20/24	85.03.30	85.06.20/24	85.06.20/24	85.03.30	85.06.20/24	85.06.20/24
Parameter										
pH	7.3	6.6	6.7	6.8	-	-	4.5	6.7 (6.76)	7.4	7.4
Acidity ($CaCO_3$) (mg/L)	4	L 1	46	90	-	-	660	170/160	45/44	53/46
Alkalinity ($CaCO_3$) (mg/L)	18	4/4	590	570	-	-	25	380/370 (386)	360	360
Conductivity (umhos/cm)	220	39/39	5,300	5,000	-	-	5,100	4,300 (4,260)	3,800	3,700
Total Dissolved Solids (105°C) (mg/L)	124	-	5,300	5,900	-	-	6,500	4,200/4,200	4,300/4,300	4,400
DOC (mg/L)	L 0.5	-	96	10.0	-	-	28	37 (22)	4.5	5.0
DIC (mg/L)	30	-	150	104/107	-	-	19.5	30 (98)	72	69/68
Kjeldahl-N (mg/L)	-	-	30	2.7	1.09		4.0		0.81	0.85/1.09
Major Anions (mg/L):										
Bromide	L 0.1	L 0.05	0.5	L 2	-	-	-	0.5 (1.0)	L 1	1
Chloride	5.1	0.7/0.8	210	270	-	-	300	180 (211)	170	160
Fluoride	0.12	0.13	0.7	0.8	-	-	0.2	1.1 (2.0)	1.3	1.1
Sulphate	80	9.2/10.9	2,900	2,900	-	-	4,300	2,700 (2,570)	2,600	2,300
Nitrate	L 0.09	0.66/0.49	L 1	L 0.2	-	-	-	L 1 (0.32)	1	1
Major Cations (mg/L):										
Magnesium	1.9//13.6	0.11/0.10	620	640	600	10.1/10.7	590	430 (460)	410//360	390
Calcium	2.9//17.1	0.15/0.15	540	470	460	8.0/8.5	440	530 (540)	500//450	480
Iron	0.11	-	101	26/25	410	56/56	420	24/26 (16)	17.3	21
Manganese	0.08	-	28	34	29	0.30/0.30	30	17.0 (14)	17.0	17.4
Silica SiO_2	1.4	-	38	38	50	32/30	36	41 (0.2)	38	42
Aluminum	0.04//0.07	-	0.61	0.84/1.1	0.58	8.3/8.7	1.4/0.77	0.73 (0.03)	1.2//0.87	0.86
Sodium	2.4//7.0	0.8/0.6	190	230/230	163	4.9/4.8	186/179	130 (140)	141//144	142/132
Potassium	0.41//0.57	0.34/0.34	19.0	8.7/8	15.2	1.62/1.52	13/13.6	6.9 (4.0)	5//5.1	4.8
Trace Cations (mg/L):										
Strontium	0.01//0.05	-	2.3	2.4/2	1.65	0.030/0.035	1.6/1.48	1.56 (0.86)	1.5//1.59	1.51
Lead	L 0.01	-	0.23	0.40	0.31	0.38/0.40	0.31	0.28 (L 0.005)	0.32	0.38
Cobalt	L 0.01	-	0.08	0.23	0.06	0.01/L 0.01	0.06	0.13 (0.011)	0.15	0.17

TABLE 5.11 GUNNAR GROUNDWATER QUALITY DATA

Location	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main
Depth from Surface	Field Blank	Field Blank	7.0 m	7.0 m	9.9 m	9.9 m	9.9 m	4.1 m	4.3 m	4.4 m
Parent Material	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Silt, very sandy, reddish brown tailings	Silt, very sandy, reddish brown tailings	Silt, very sandy, reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings	Sand, silty reddish brown tailings
Field Code	GM1C	GM1C	GM2B	GM2B	GM3B	GM3B (filtered material on mg/L basis)	GM3B	GM3C (alternate lab blind replicate)	GM3D	GM3E
Date	85.06.20/24	85.08.25	85.03.30	85.06.20/24	85.03.30	85.06.20/24	85.06.20/24	85.03.30	85.06.20/24	85.06.20/24
Parameter										
Nickel	L 0.01	-	0.05	0.05	0.07	0.02/0.01	0.05	0.04 (0.007)	0.04	0.05
Zinc	L 0.01	-	0.135	0.115	0.255	0.05/0.03	0.150	0.100 (0.004)	0.070	0.095
Chromium	L 0.01	-	0.04	0.04	0.03	0.11/0.10	0.03	0.04 (0.013)	0.03	0.04
Copper	L 0.005	-	0.030	0.025	0.030	0.04/0.04	0.020	0.030 (0.012)	0.010	0.010
Cadmium	L 0.005	-	0.050	0.030	0.150	0.03/L 0.01	0.100	0.030 (L 0.001)	0.015	0.025
Barium	L 0.01//L 0.01	-	L 0.01	0.03	L 0.01	0.15/0.16	L 0.05/0.04	L 0.01 (0.037)	L 0.05//0.04	0.03
Vanadium	L 0.01//L 0.01	-	0.06	0.03	0.02	0.03/0.02	0.05/0.04	0.03 (0.10)	L 0.05//0.04	0.04
Titanium	-	-	0.46	-	0.40	-	-	0.46 (0.004)	-	-
Arsenic (ug/L)	-	-	136	-	24	-	-	112 (80)	-	-
Selenium (ug/L)	-	-	-	-	-	-	-	-	-	-
Molybdenum	L 0.01//L 0.01	-	0.15	0.14	0.15	0.01/0.01	0.2/0.11	0.14 (0.03)	0.2//0.14	0.14
Beryllium	L 0.01//L 0.01	-	L 0.01	L 0.01	L 0.01	L 0.01/L 0.01	L 0.01	L 0.01 (0.002)	L 0.05//L 0.01	L 0.01
Sum Anions	2.17	0.31	78	79.3	-	-	98.4	68.8 (67.1)	66.1	59.6
Sum Cations	2.37	0.06	87.6	88.1	(79.7)	-	92.1	71.0 (74.2)	65.8	66.6
Tritium (T.U.)	-	-	-	-	-	-	-	-	-	-
Radionuclides										
Uranium (ug/L)	13±3	L 0.5	3,500	18,200 16,700**	-	-	55±5 37±3**	11,500 (13,500/14,000)	11,400 9,500**	11,600
Thorium-230 (Bq/L)	-	-	-	- L 0.02**	-	-	-	0.119±0.006 (0.063±0.005)	-	-
Radium-226 (Bq/L)	-	0.04	4.7	- 2.5**	-	-	-	1.9 (2.94±0.04/ 3.05±0.06)	-	-
Lead-210 (Bq/L)	-	0.05	2.5	- 0.60**	-	-	-	3.0 (2.43±0.23/ 5.34±0.43)	-	-
Polonium-210 (Bq/L)	-	-	0.60	-	-	-	-	0.02 (0.408±0.076/ 1.23±0.21)	-	-
Radium-228 (Bq/L)	-	-	-	-	-	-	-	-	-	-
Thorium-232 (Bq/L)	-	L 0.04	-	L 0.02**						
Thorium-228 (Bq/L)	-	L 0.04	-	L 0.02**						

L : Less than.
** Sampled August 1985.

TABLE 5.12 GUNNAR GROUNDWATER QUALITY DATA

Location	Gunnar Main
Depth from Surface	4.1 m
Parent Material	Sand, silty reddish brown tailings
Field Code	GM3F (SRC)
Date	85.03.30
Parameter	
pH	6.76
Acidity ($CaCO_3$) (mg/L)	-
Alkalinity ($CaCO_3$) (mg/L)	386
Conductivity (umhos/cm)	4,260
Total Dissolved Solids (105°C) (mg/L)	4,430
DOC (mg/L)	22
DIC (mg/L)	98
Kjeldahl-N (mg/)	-
Major Anions (mg/L):	
Bromide	1.0
Chloride	211
Fluoride	2.0
Sulphate	2,570
Nitrate	-
Major Cations (mg/L):	
Magnesium	460
Calcium	540
Iron	16
Manganese	14
Silica SiO_2	0.2
Aluminum	0.03
Sodium	140
Potassium	4.0
Trace Cations (mg/L):	
Strontium	0.86
Lead	L 0.005
Cobalt	0.011

TABLE 5.12 GUNNAR GROUNDWATER QUALITY DATA

Location	Gunnar Main
Depth from Surface	4.1 m
Parent Material	Sand, silty reddish brown tailings
Field Code	GM3F (SRC)
Date	85.03.30
Parameter	
Nickel	0.007
Zinc	0.004
Chromium	0.013
Copper	0.012
Cadmium	L 0.001
Barium	0.037
Vanadium	0.10
Titanium	0.004
Arsenic (ug/L)	80
Selenium (ug/L)	-
Molybdenum	0.03
Beryllium	0.002
Sum Anions	-
Sum Cations	-
Tritium (T.U.)	-

L = Less than.

TABLE 5.13 GUNNAR GROUNDWATER QUALITY DATA

Location	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main
Depth from Surface	4.7 m	4.7 m	3.5 m	3.0 m	1.8 m	6.9 m	3.1 m	3.3 m	1.8 m
Parent Material	Clay, medium plastic, grey-brown	Clay, medium plastic, grey-brown	Sand, silty reddish brown tailings	Silt, trace of sand, reddish brown tailings	Silt, trace of sand, reddish brown tailings	Silt, trace of sand, reddish brown tailings	Silt, trace of sand, reddish brown tailings	Sand, silty reddish brown tailings	Silt, reddish brown tailings
Field Code	GM4B	GM4B (blind field sequenced)	GM9C	GM12A	GM12B	GM13A	GM13B	GM17B	GM17C
Date	85.03.20	85.03.20	85.03.12	85.03.24	85.03.24	85.03.23	85.03.23	85.03.19	85.03.19
Parameter									
pH	6.6	6.8	6.4	6.8	7.5	5.8	5.4	6.4	4.7
Acidity ($CaCO_3$) (mg/L)	26/36	81	93	280	70	870	1,120	400	320
Alkalinity ($CaCO_3$) (mg/L)	300	270/280	930	600	620	77	28	240	L 1
Conductivity (umhos/cm)	2,800	2,900/2,800	6,430	4,880	4,500	6,850	6,900	4,480	2,350
Total Dissolved Solids (105°C) (mg/L)	2,900	2,800	7,100/7,200	5,500	5,200	8,700/8,700	8,600	5,100	5,900
DOC (mg/L)	30	38	50	146	196	98	46	43	48
DIC (mg/L)	70	80	180	230	100	21	30	60	25/35
Kjeldahl-N (mg/L)	3.1	4.0	11.7	11.7	3.5	24	7.8	2.4	7.4
Major Anions (mg/L):									
Bromide	L 0.3	0.2	0.8	0.8	0.9	1/1	1.4/1.0	0.5	0.9
Chloride	72/72/73	80/90	41	280/300	160	320	340	176	246
Fluoride	0.4/0.6	0.6	0.8/0.6	0.2/0.3	0.2	0.3/0.4	0.3/0.3	0.5	0.2
Sulphate	1,640	1,780	3,900	2,900	2,800	5,400	5,200	3,100	3,600
Nitrate	L 1	L 1	L 1	L 1	L 1	L 1	L 2	L 1	L 1
Major Cations (mg/L):									
Magnesium	137	134/132	850	-	-	940	910	430	560
Calcium	620	620/640	510	-	-	440	410	490	510
Iron	86	75	310	-	-	710	650	420	520
Manganese	8.6/8.4	8.4/7.8	37	-	-	38	39	18.4	25
Silica SiO_2	55	54	53	-	-	66	56	63	41
Aluminum	0.75	0.75/0.70	0.68	-	-	0.42	0.92	0.53	0.68
Sodium	64	66/63	260	-	-	250	250	115	170
Potassium	7.8	9.6/8.8	15.2	-	-	13.0	11.9	15.7	10.1
Trace Cations (mg/L):									
Strontium	1.20	1.20/1.19	1.76	-	-	1.40	1.32	1.32	1.38
Lead	0.17/0.18	0.17	0.25	-	-	0.32	0.36	0.26	0.28
Cobalt	0.04/0.04	0.04	0.05	-	-	0.06	0.07	0.06	0.07

TABLE 5.13 GUNNAR GROUNDWATER QUALITY DATA

Location	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main
Depth from Surface	4.7 m	4.7 m	3.5 m	3.0 m	1.8 m	6.9 m	3.1 m	3.3 m	1.8 m
Parent Material	Clay, medium plastic, grey-brown	Clay, medium plastic, grey-brown	Sand, silty reddish brown tailings	Silt, trace of sand, reddish brown tailings	Silt, trace of sand, reddish brown tailings	Silt, trace of sand, reddish brown tailings	Silt, trace of sand, reddish brown tailings	Sand, silty reddish brown tailings	Silt, reddish brown tailings
Field Code	GM4B	GM4B (blind field sequenced)	GM9C	GM12A	GM12B	GM13A	GM13B	GM17B	GM17C
Date	85.03.20	85.03.20	85.03.12	85.03.24	85.03.24	85.03.23	85.03.23	85.03.19	85.03.19
Parameter									
Nitrite									
Nickel	0.04/0.04	0.05	0.04	-	-	0.09	0.08	0.05	0.08
Zinc	0.060/0.065	0.075	0.160	-	-	0.28	0.24	0.140	0.22
Chromium	0.03/0.04	0.03	0.04	-	-	0.03	0.04	0.04	0.08
Copper	0.020/0.020	0.025	0.020	-	-	0.025	0.040	0.035	0.040
Cadmium	0.045/0.045	0.050	0.120	-	-	0.240	0.22	0.160	0.180
Barium	L 0.01	L 0.01/L 0.01	L 0.01	-	-	L 0.01	L 0.01	L 0.01	L 0.01
Vanadium	0.04	0.03/0.03	0.05	-	-	0.04	0.02	0.03	0.05
Titanium	0.37/0.49	0.37	0.35	-	-	0.34/0.43	0.34	0.33	0.34
Arsenic (ug/L)	28	24	24/25	-	-	24	30	20	96
Selenium (ug/L)	-	-	-	-	-	-	-	-	-
Molybdenum	0.16	0.14/0.15	0.18	-	-	0.17	0.16	0.13	0.18
Beryllium	L 0.01	L 0.01/L 0.01	L 0.01	-	-	L 0.01	0.01	L 0.01	L 0.01
Sum Anions	42.2	44.9	101	80.5	75.1	123	118	74.2	81.8
Sum Cations	45.9	46.4	109	-	-	128	128	73.2	85.5
Tritium (T.U.)	-	-	-	-	97	-	-	-	-
Radionuclides									
Uranium (ug/L)	120±10	100±9	-	-	-	-	-	100±9	-
Thorium-230 (Bq/L)	-	-	-	-	-	-	-	-	-
Radium-226 (Bq/L)	0.90	0.85	-	-	-	-	-	0.90	-
Lead-210 (Bq/L)	1.1	1.0	-	-	-	-	-	0.60	-
Polonium-210 (Bq/L)	0.22	0.20	-	-	-	-	-	0.70	-

L = Less than.

TABLE 5.14 GUNNAR GROUNDWATER QUALITY DATA

Location	Gunnar Main	Gunnar Main	St. Mary's Channel	St. Mary's Channel	St. Mary's Channel
Depth from Surface	3.9 m	2.7 m			
Parent Material	Sand-silt reddish brown tailings	Sand-silt reddish brown tailings	Equipment rinse water Sample 1	Equipment rinse water Sample 1	Equipment rinse water Sample 2
Field Code	GM19B	GM19C	SM1	SM1	SM2
Date	85.03.21	85.03.21	85.06.24	85.08.24	85.06.24
Parameter					
pH	6.4	5.8	7.3	7.4	7.5
Acidity ($CaCO_3$) (mg/L)	180	330	4	-	4
Alkalinity ($CaCO_3$) (mg/L)	260/280	96	24/23	21	26
Conductivity (umhos/cm)	5,580	4,980	95/102	106/114	75/82
Total Dissolved Solids (105°C) (mg/L)	6,000	5,800	65	-	53
DOC (mg/L)	24	49	5.0	-	2.5
DIC (mg/L)	35	45	4.5	-	4.5
Kjeldahl-N (mg/L)	10.9/9.6	2.3	0.19	-	0.19
Major Anions (mg/L):					
Bromide	0.8	0.4	-	0.05	-
Chloride	270	240	3.7	4.0	3.3
Fluoride	0.9	0.8	0.08	0.06	0.07
Sulphate	3,700	3,700	19	12.5	8.0
Nitrate	L 1	L 1	0.13	0.66	0.09
Major Cations (mg/L):					
Magnesium	660	630	3.0//3.9	2.4	2.4//2.6
Calcium	490	460	9.2//10.2	6.9	8.0//8.4
Iron	380	280	0.05	-	0.06
Manganese	31	27	0.01	-	L 0.01
Silica SiO_2	50/47	48	3.2	-	3.3/3.4
Aluminum	0.62	0.49	0.03//0.04	-	0.02//0.03
Sodium	175	170	3.3//3.4	2.6	3.2//3.3
Potassium	11.4	5.3	1.02//1.07	1.20	1.05//1.07
Trace Cations (mg/L):					
Strontium	2.0	2.2	0.06//0.07	-	0.06//0.07
Lead	0.25	0.24	0.02	-	0.02
Cobalt	0.10	0.11	L 0.01	-	L 0.01

TABLE 5.14 GUNNAR GROUNDWATER QUALITY DATA

Location	Gunnar Main	Gunnar Main	St. Mary's Channel	St. Mary's Channel	St. Mary's Channel
Depth from Surface	3.9 m	2.7 m			
Parent Material	Sand-silt reddish brown tailings	Sand-silt reddish brown tailings	Equipment rinse water Sample I	Equipment rinse water Sample I	Equipment rinse water Sample 2
Field Code	GM19B	GM19C	SM1	SM1	SM2
Date	85.03.21	85.03.21	85.06.24	85.08.24	85.06.24
Parameter					
Nickel	0.14	0.11	L 0.01	-	L 0.01
Zinc	0.135	0.145	0.010	-	0.010
Chromium	0.03	0.03	L 0.01	-	L 0.01
Copper	0.035	0.035	L 0.005	-	0.010
Cadmium	0.145	0.130	0.010	-	0.010
Barium	L 0.01	L 0.01	0.01//0.01	-	0.01//0.01
Vanadium	0.04	0.03	L 0.01//L 0.01	-	L 0.01//L 0.01
Titanium	0.34	0.35	-	-	-
Arsenic (ug/L)	136	176	-	-	-
Selenium (ug/L)	-	-	-	-	-
Molybdenum	0.14	0.15	L 0.01//L 0.01	-	L 0.01//L 0.01
Beryllium	L 0.01	L 0.01	L 0.01//L 0.01	-	L 0.01//L 0.01
Sum Anions	90.0	85.7	0.96	0.79	0.78
Sum Cations	90.2	88.9	0.96	0.69	0.84
Tritium (T.U.)	-	-	-	-	-
Radionuclides					
Uranium (ug/L)	350±30	-	2.0±0.4	L 0.5	1.9±0.4
Thorium-230 (Bq/L)	-	-	-	L 0.04	-
Radium-226 (Bq/L)	1.6	-	-	0.02	-
Lead-210 (Bq/L)	0.50	-	-	L 0.08	-
Polonium-210 (Bq/L)	0.22	-	-	-	-
Radium-228 (Bq/L)	-	-	-	-	-
Thorium-232 (Bq/L)	-	-	-	L 0.04	-
Thorium-228 (Bq/L)	-	-	-	L 0.04	-

L = Less than.

TABLE 5.15 GUNNAR GROUNDWATER QUALITY DATA

Location	East of Berm off Gunnar Main	East of Berm off Gunnar Main	East of Berm off Gunnar Main
Depth from Surface	0.9 m	1.0 m	1.0 m
Parent Material	Tailings and underlying soil interface	Silty clay just under tailings	Reddish brown tailings
Field Code	GM22	GM23	GM24
Date	85.06.24	85.06.24	85.06.24
Parameter			
pH	6.8	8.1	7.0
Acidity ($CaCO_3$) (mg/L)	16	8	66
Alkalinity ($CaCO_3$) (mg/L)	68	198	70
Conductivity (umhos/cm)	2,000	2,400	4,700
Total Dissolved Solids (105°C) (mg/L)	2,200	2,600	5,700
DOC (mg/L)	10.0	6.5	14.5
DIC (mg/L)	13.0	37/32	23
Kjeldahl-N (mg/L)	0.27	0.47	1.84
Major Anions (mg/L):			
Bromide	L 1	-	L 2
Chloride	2.4	39	420/410
Fluoride	0.1	0.7	0.3
Sulphate	1,450	1,640	3,000
Nitrate	L 0.9	L 0.9	L 2
Major Cations (mg/L):			
Magnesium	62//73*	89//94	530//510
Calcium	490//460	560//530	450//420
Iron	0.44	1.19	36
Manganese	1.73	3.4	10.9
Silica SiO_2	34/32	45	49
Aluminum	1.1//0.87	1.4//0.99	1.1//0.66
Sodium	16//18.0	45//47*	210//204
Potassium	1.3//1.67	4//4.1	8//8
Trace Cations (mg/L):			
Strontium	1.2//1.25	1.3//1.36	1.3//1.2
Lead	0.26	0.20	0.20
Cobalt	0.05	0.06	0.04

TABLE 5.15 GUNNAR GROUNDWATER QUALITY DATA

Location	East of Berm off Gunnar Main	East of Berm off Gunnar Main	East of Berm off Gunnar Main
Depth from Surface	0.9 m	1.0 m	1.0 m
Parent Material	Tailings and underlying soil interface	Silty clay just under tailings	Reddish brown tailings
Field Code	GM22	GM23	GM24
Date	85.06.24	85.06.24	85.06.24
Parameter			
Nickel	0.03	0.03	0.03
Zinc	0.165	0.185	0.175
Chromium	0.03	0.03	0.02
Copper	0.030	0.015	0.020
Cadmium	0.005	0.010	0.025
Barium	L 0.05//0.04	L 0.05//0.04	L 0.05//0.04
Vanadium	L 0.05//0.03	0.05//0.04	L 0.05//0.03
Titanium	-	-	-
Arsenic (ug/L)	-	-	-
Selenium (ug/L)	-	-	-
Molybdenum	0.2//0.11	0.2//0.12	0.2//0.2
Beryllium	L 0.05//L 0.01	L 0.05//L 0.01	L 0.05//L 0.01
Sum Anions	31.6	39.2	75.5
Sum Cations	30.6	37.5	76.7
Tritium (T.U.)	-	-	-
Radionuclides			
Uranium (ug/L)	200	-	400
Thorium-230 (Bq/L)	-	-	-
Radium-226 (Bq/L)	2.0	-	-
Lead-210 (Bq/L)	1.0	-	-
Polonium-210 (Bq/L)	-	-	-
Radium-228 (Bq/L)	-	-	-

L = Less than.

* Average value.

TABLE 5.16 GUNNAR GROUNDWATER QUALITY DATA

Location	Seepage off South End Gunnar Main	Seepage Creek on East Side of Waste Rock Pile	Seepage Creek on East Side of Waste Rock Pile	South End of Waste Rock Pile	East Side of Waste Rock Pile	East Side of Waste Rock Pile	East Side of Waste Rock Pile Near Seepage Creek
Depth from Surface	Surface	Surface	Surface	1 m	1 m	1 m	1 m
Parent Material	Surface pool in sandy tailings	Surface flow in small creek approx. 3 L/s	Surface flow in small creek approx. 1 L/s	Varved silty-clay	Varved silty-clay	Varved silty-clay	Varved silty-clay
Field Code		WRS	WRS	WRP1	WRP2	WRP3	WRP4
Date	85.06.23	85.06.20/24	85.08.28	85.06.20/24	85.06.20/24	85.06.20/24	85.06.20/24
Parameter							
pH	8.2	7.8 (8.3)	6.1	4.8	7.8	7.2	7.8
Acidity (CaCO$_3$) (mg/L)	4	4	-	82	10	8	8
Alkalinity (CaCO$_3$) (mg/L)	255	107 (116)	39	L 1	78	19	94
Conductivity (umhos/cm)	3,000	1,380	580	2,300	850	1,550	1,310
Total Dissolved Solids (105°C) (mg/L)	3,400/3,300	1,380 (1,380)	-	2,400	700	1,510	1,120
DOC (mg/L)	L 0.5	14.0 (16)	34	10.0	7.5	9.5	15.0
DIC (mg/L)	41	17.0 (25)	-	L 0.5	21	L 0.5	24
Kjeldahl-N (mg/L)	0.04/0.03	0.35	-	1.60	0.50/0.50	2.7	0.91
Major Anions (mg/L):							
Bromide	L 1	L 0.5 (0.20)	-	2/1	-	0.6	1.9
Chloride	56	20 (14)	8.0/7.5	84/78	22	37/34	144
Fluoride	0.5	0.5 (0.78)	0.4/0.4	2.1	0.1	0.8/0.9	0.3
Sulphate	1,840	770 (930)	270	1,450	360	1,020	640
O-Phosphate	-	-	L 0.1	-	-	-	-
Nitrate	L 1.3	L 0.5	0.5	7.1/6.2	L 0.2	15.5	L 0.5
Nitrite	-	-	L 0.1	-	-	-	-
Major Cations (mg/L):							
Magnesium	250//260	29//59 (70)	39	98//110	40//55*	69//70	82//87
Calcium	480//470	99//290 (298)	74	310//340	89//85*	194//195	133//138
Iron	0.86	0.27 (0.34)	0.26	0.30	0.78	0.04	0.03
Manganese	1.20	0.20 (0.25)	0.43	10.5	0.42	7.4	1.23
Silica SiO$_2$	28	13.7 (7.5)	6.3	50	18.6	61	27
Aluminum	1.0//0.84	0.72//0.96 (0.65)	0.40	7.4//11.1	0.2//0.32	1.02//1.89	0.04//0.04
Sodium	80//84*	12.0//25 (43)	14.3	187//144	33//38*	98//99	78//81
Potassium	4//4.4	1.52//2.4 (2.3)	5.3	10.3//10.2	6.9//7.1	9.1//9.5	8.8//9.1
Trace Cations (mg/L):							
Strontium	1.4//1.44	0.25//0.67 (0.47)	0.39	1.42//1.55	5.5//5.8	0.86//0.91	1.18//1.26
Lead	0.26	0.06 (L 0.005)	0.33	0.10	0.05	0.08	0.06
Cobalt	0.10	0.02 (0.002)	0.22	0.16	0.03	0.20	0.02

TABLE 5.16 GUNNAR GROUNDWATER QUALITY DATA

Location	Seepage off South End Gunnar Main	Seepage Creek on East Side of Waste Rock Pile	Seepage Creek on East Side of Waste Rock Pile	South End of Waste Rock Pile	East Side of Waste Rock Pile	East Side of Waste Rock Pile	East Side of Waste Rock Pile Near Seepage Creek
Depth from Surface	Surface	Surface	Surface	1 m	1 m	1 m	1 m
Parent Material	Surface pool in sandy tailings	Surface flow in small creek approx. 3 L/s	Surface flow in small creek approx. 1 L/s	Varved silty-clay	Varved silty-clay	Varved silty-clay	Varved silty-clay
Field Code		WRS	WRS	WRP1	WRP2	WRP3	WRP4
Date	85.06.23	85.06.20/24	85.08.28	85.06.20/24	85.06.20/24	85.06.20/24	85.06.20/24
Parameter							
Nickel	0.02	0.01 (0.008)	0.025	0.62	0.02	0.34	0.04
Zinc	0.040	0.015 (0.049)	0.020	0.84	0.040	0.39	0.26
Chromium	0.03	L 0.01 (0.002)	0.010	0.01	L 0.01	0.01	L 0.01
Copper	0.010	0.015 (0.031)	0.015	0.020	L 0.005	0.015	0.010
Cadmium	0.010	L 0.005 (L 0.001)	0.005	0.015	0.005	0.020	0.010
Barium	L 0.05//0.03	0.03//0.04 (0.058)	0.040	0.02//0.02	0.02//0.03	0.02//0.02	0.02//0.02
Vanadium	L 0.05//0.04	0.01//0.02 (0.01)	0.015	0.02//0.02	L 0.01//0.01	0.02//0.02	0.01//0.01
Titanium	-	-	0.11	-	-	-	-
Arsenic (ug/L)	-	-	-	-	-	-	-
Selenium (ug/L)	-	-	-	-	-	-	-
Molybdenum	0.1//0.12	0.04//0.08 (0.006)	0.07	0.08//0.08	0.03//0.04	0.06//0.06	0.04//0.05
Beryllium	L 0.05//L 0.01	L 0.01//L 0.01 (L 0.001)	L 0.005	L 0.01//0.01	L 0.01//L 0.01	L 0.01//L 0.01	L 0.01//L 0.01
Sum Anions	45.0	18.7 (22.1)	-	32.4	9.67	22.6	19.3
Sum Cations	48.2	20.5 (22.3)	-	33.6	9.54	22.0	17.2
Tritium (T.U.)	-	-	-	-	-	-	-
Radionuclides							
Uranium (ug/L)	6,900	2,000	-	-	1,800	-	-
Thorium-230 (Bq/L)	-	-	-	-	-	-	-
Radium-226 (Bq/L)	3.5	1.1	-	-	-	-	-
Lead-210 (Bq/L)	0.5	0.05	-	-	-	-	-
Polonium-210 (Bq/L)	-	-	-	-	-	-	-
Radium-228 (Bq/L)	-	-	-	-	-	-	-

L = Less than.

* Average value.

5.5 DISCUSSION OF RESULTS

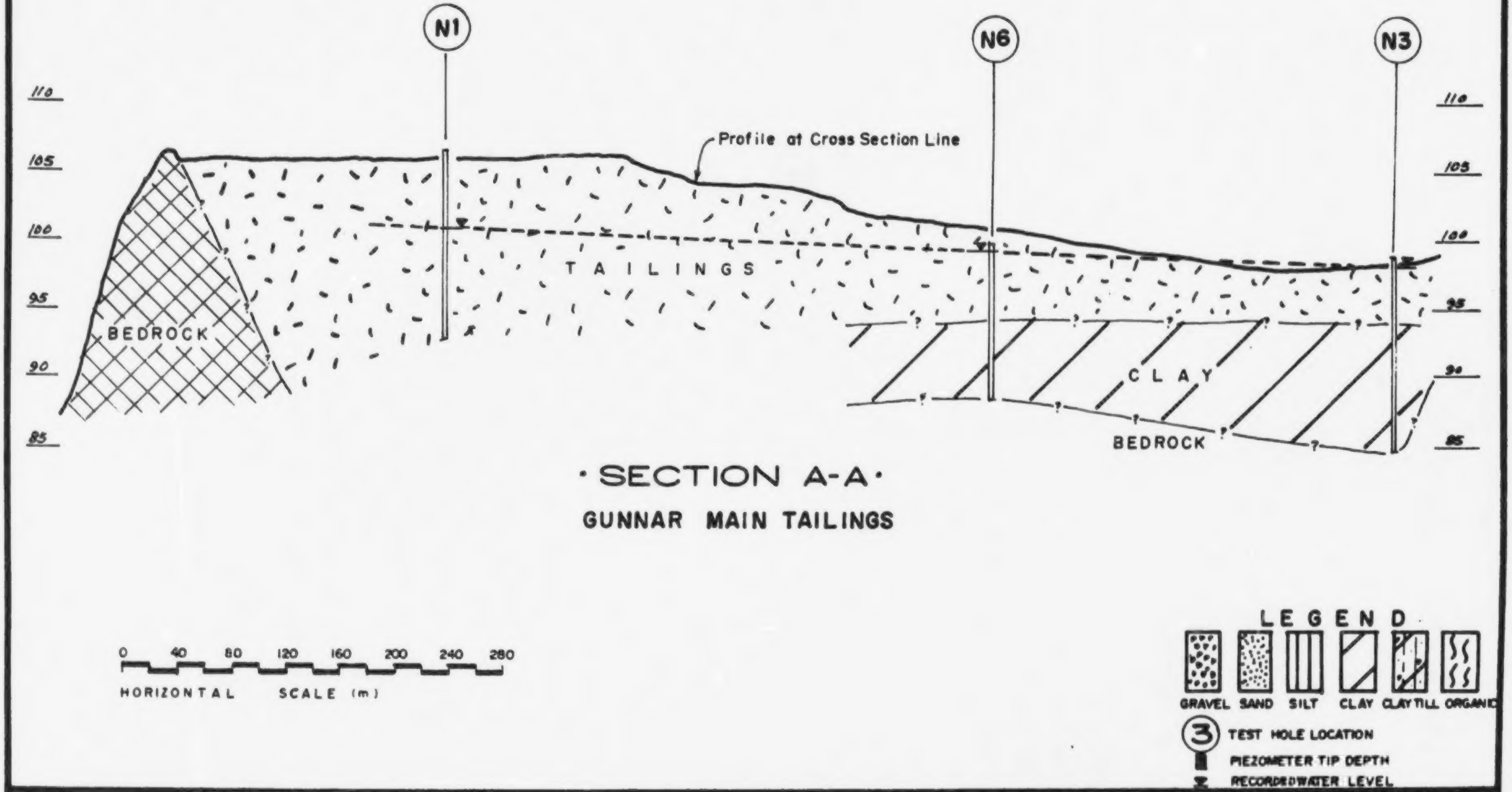
5.5.1 Static Water Level Elevations and Flow

A general overview of the water level data obtained to date shows that movement of porewater through the Gunnar Main Tailings area is from the southeast to the northwest and north. It is essentially moving from the topographic high to the topographic low and eventually discharges along the western edge of the site and moves northward via the surface water route through the outlet at the north end of the site. The data indicate a general downward gradient along the topographic high areas (i.e. N1), indicating recharge. An upward gradient appeared to exist along the southern portion (i.e. GM13) of the topographic low indicating discharge areas. In the northern portion of Gunnar Main, the shallow groundwater zone indicated a downward gradient at least part of the year. Figure No. 5.5 is a typical section through Gunnar Main showing the slope of the groundwater table.

Water levels indicated that the depth to the water table varied from ground surface or just below it along the western portion of the Gunnar Main tailings to about 4 m below ground surface in the recharge area. Water level trends indicated a general increase in water levels in the late winter and spring and a decline in the summer months. The actual change from increasing water levels to decreasing levels depends on the location of the local flow system. Water levels fluctuated by about 1.0 to 1.5 m. The smallest fluctuation appeared to be in the recharge area.

Water levels in the Gunnar Central Tailings, although data are limited, indicated upward gradients in the central portion of the site. Depth to water is about 1.0 m. There was a slight decline in water levels during the summer months.

Water levels in the Langley Bay Tailings indicated an upward gradient in the central portion of the site and downward at either end of the tailings. This downward gradient may be the result of increasing lake levels "recharging" the lower elevation areas of the tailings as the lake levels rise.


N1
N6
N3
110
105
100
95
90
85
Profile at Cross Section Line
TAILINGS
BEDROCK
CLAY
BEDROCK
0 40 80 120 160 200 240 280
HORIZONTAL SCALE (m)
LEGEND
GRAVEL
SAND
SILT
CLAY
CLAYTILL
ORGANIC
3 TEST HOLE LOCATION
PIEZOMETER TIP DEPTH
RECORDED WATER LEVEL

·SECTION A-A·

GUNNAR MAIN TAILINGS

Geotechnical Consultants Ltd.

INTERPRETED SUBSOIL STRATIGRAPHY

NOTE: THE INFERRED SOIL STRATIFICATION HAS BEEN INTERPRETED FROM DATA OBTAINED AT TEST HOLE LOCATIONS ONLY. THE INFERRED CONTACTS SHOWN ARE BASED ON GEOLOGICAL EVIDENCE AND MAY VARY FROM THOSE SHOWN BETWEEN TEST HOLES.

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GUNNAR FIELD STUDY
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FIGURE 5.5

5.5.2 Hydraulic Conductivity Tests

Response data which were analyzed showed a general range of hydraulic conductivities from 1E-03 cm/sec to 1E-06 cm/sec. The shallow coarse fraction of the tailings had the highest hydraulic conductivity while at depth in the sandy tailings, the hydraulic conductivity was on the order of 2E-04 cm/sec. In the fine fraction of tailings, such as the topographic low on Gunnar Main and the tailings in Langley Bay, hydraulic conductivities were in the order of 1E-06 cm/sec. It should also be cautioned that some of these tests were slow responding if they were located in ice lenses and portions of the water column were frozen. These data should be interpreted along with data from Volume 10, Appendix 9. In general, very good agreement was found between field and laboratory hydraulic conductivity values.

5.5.3 Groundwater Chemistry

A review of the groundwater data collected from Gunnar Main, Gunnar Central and Langley Bay had a consistent general water chemistry. The system is dominated by calcium sulphates with lesser quantities of carbonate and chlorides. The insitu pH was between 7 and 8. Several samples showed pH values of near 4 in the laboratory which may be due to reduced iron hydroxide precipitating in the bottles after collection. Calculations have shown that in these samples (e.g. N5C), the precipitation of 600 mg/l of Fe^{++} to Fe^{+++} will result in a pH drop of 3 units (i.e. from 7 to 4). In all cases where field and laboratory pH values were measured, there was a lower laboratory pH due to iron precipitation. It is also suspected based upon the iron floc bailed from the piezometer that iron precipitation has occurred to some extent in the piezometers and field pH values measured may be lower than actual insitu pH values.

The conductivity in the main mass of the tailings was generally observed to range between 2,000 and 6,000 umhos/cm. In recharge areas that are being washed by meteoric water, the conductivity was lower, typically near 3,000 umhos/cm.

Physical hydrogeology showed that the wet section northwest of the tailings represented a discharge zone with recharge occurring to the southeast. There appeared to be a trend in porewater chemistry of increasing dissolved solids concentrations from the recharge area toward the discharge zones. To a great extent, the porewater chemistry was controlled by solubility of certain solids including gypsum that can maintain relatively stable concentrations in the porewater, but there was some effect of travel distance reflecting increasing concentrations of some other dissolved substances (e.g. magnesium). An additional control on porewater concentrations in the discharge areas was evaporation. This process leads to concentration of very soluble substances in the porewater. Magnesium salts, for example, are more soluble than calcium salts and therefore, magnesium was observed to be noticeably more concentrated in porewater in the discharge area near ground surface. The trends in the solids also reflected these processes.

In the discharge areas typified near location N2 at the base of the tailings (depth 12 m), the sulphate in the solids was near 13,000-15,000 ppm increasing rapidly near 5 m to 27,000 ppm (near 5 m) and 67,000 ppm near 3.5 m depth. At 0.5 m below the surface, the sulphate in the solids increased to 88,000 ppm. These geochemical data show a mobilization in recharge areas and precipitation in discharge areas. The major cations, trace metals and radionuclides generally followed major anions such as sulphate.

Some of the groundwater from Gunnar Main appears to mix with surface water and flows down into Gunnar Central. This flow appears to seep into the tailings until saturation is achieved and then overland flow occurs. This seasonal process of seepage recharge and discharge would result in the buildup of soluble salts in tailings solids and porewaters near the surface related to evaporative concentration. Porewater in the clay underlying Gunnar Central displayed sulphate levels that were generally less than 1,000 ppm increasing into the low thousands at a depth of 2.3 m (N4C) and to over 10,000 mg/l at a depth of 1.3 m.

Porewater sampled from near the phreatic surface in Gunnar Central showed a marked evaporative seasonal concentration with total dissolved solids going from 18,000 ppm in December to over 50,000 ppm in June. These Gunnar Central tailings showed the highest levels of sulphate in the solid phase being over 100,000 ppm or 10 percent. By contrast the surface tailings in Langley Bay showed sulphates as low as 5,000 ppm/g. The relatively high reservoir of readily mobilized salts in Gunnar Central concentrated there by years of seasonal evaporation are available for discharge during wet periods when the water table in Gunnar Central rises and overland flow out of the rock basin into Langley Bay occurs. The water quality of this overland flow will be a result of dilution of near surface porewater as typified by data from N4D and meteoric water flowing down from Gunnar Main.

Within Gunnar Central, there appeared to be some unique geochemical processes occurring. In the winter, under the surface of the frozen tailings, the chemistry showed moderate levels of magnesium and calcium sulphate at the 1.3 m depth. At this location in Gunnar Central, the magnesium levels are much higher than the calcium. This is in contrast to levels on Gunnar Main and in Langley Bay where the levels of calcium and magnesium at near neutral pH values were about equal. The reason for this appears to be related to pH. When the pH in an area of tailings porewater drops because of the penetration of oxygen and the resultant oxidation of iron, the magnesium solids dissolve and the level of magnesium sulphate increases dramatically. This is what appears to be happening seasonally in Gunnar Central when the level of magnesium increases with a drop in pH while the level of calcium stays just about constant. The leaching data on the solids in Gunnar Central showed that the calcium salts ($CaSO_4$) are very soluble as expected (95 percent dissolve), while under the near neutral water leaching conditions the magnesium salts appeared relatively insoluble (about 2.5 percent dissolve). Under acidic leaching conditions, virtually all of the magnesium dissolves (97 percent). It would then appear that seasonal iron precipitation and resolubilization results in pH shifts which in turn may affect the solubility of magnesium and other trace metals.

In Langley Bay, which over the long term is subjected to much more flushing than Gunnar Central, the levels of calcium and magnesium were similar at the low pH values. In the Langley Bay area (LB7A), the surface tailings have been leached and water soluble calcium was only 50 to 60 percent of the total calcium, and water soluble magnesium 1.5 percent of the total magnesium, as compared to 95 percent and 2.5 percent respectively on Gunnar Central at the surface and 96 percent and 1.8 percent respectively on Gunnar Main (N2E).

Other phenomena were observed on Gunnar Central. During the summer a white salt crust appeared on parts of Gunnar Central. Samples collected in June near the head of Gunnar Central (CG7) and leached in the laboratory suggested that the crust is composed of calcium sulphate with close to the same amount of magnesium sulphate. Of the total magnesium present, however, close to 60 percent was sparingly soluble (acid soluble). About 100 m further down Gunnar Central (GC8), near a pond of standing water, this same crust was predominantly magnesium sulphate with minor amounts of calcium sulphate. These surface precipitates then appear to reflect the iron mediated geochemical mobilization processes occurring with the tailings porewater and subsequent evaporation, concentration, and precipitation.

The levels of Ra-226 within the porewaters of Gunnar Main typically showed values of 1-3 Bq/l with some values as high as 7 Bq/l. Specific activity levels of other radionuclides in solution were typically lower than those of radium. Uranium values in the main tailings porewater were typically 1-3 mg/l with some areas (N1C) being as high as 8 mg/l. In the discharge areas (N3 and N6), the uranium values were lower (0.1-0.3 mg/l). Thorium-230 values were the lowest of all of the U-238 decay series radionuclides, reflecting the low solubility of thoriums in neutral and basic waters. The natural thorium isotopes showed an activity abundance of less than 10 percent of the uranium series in the tailings solids and were at levels below the detection limit in the tailings porewater.

In summary, the tailings porewater geochemistry reflects the patterns of recharge and discharge shown by the hydrogeological investigations. The geochemical analyses also show a series of solubilization and reprecipitation areas in the tailings where seasonal concentrations of calcium and magnesium sulphates and possibly hydroxides dissolve and reprecipitate. Iron oxidation and reduction processes appeared to be a major factor in controlling local seasonal pH shifts and pH mediated mobilization reactions, which in turn control trace element and radionuclide levels in shallow groundwater.

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THE GUNNAR FIELD STUDY

The Gunnar Field Study consists of 10 volumes, each published separately. Volumes 2 to 10 are supplements to Volume 1, written as Appendices 1 to 9.

The volumes are:

- Volume 1 - Summary Report
- Volume 2 - Test Procedures and QA/QC Program (Appendix 1)
- Volume 3 - Atmospheric Studies (Appendix 2)
- Volume 4 - Tailings Solids and Surrounding Soils (Appendix 3)
- Volume 5 - Groundwater (Appendix 4)
- Volume 6 - Surface Water (Appendix 5)
- Volume 7 - Biology (Appendix 7)
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6.0 SUMMARY OF SURFACE WATER STUDIES

All of the surface water runoff from Gunnar Main discharges to the north through a small bedrock gap, through a marshy area and then down through a steep sided bedrock valley into Gunnar Central. During the spring, snow melt causes substantial water flow from Gunnar Main to Gunnar Central and from Gunnar Central to Langley Bay. During drier months, water seeps from Gunnar Main into Gunnar Central and evaporates or ceases to flow almost completely. If there is sufficient groundwater in Gunnar Central, it discharges over a bedrock lip and down through one of two stream channels to Langley Bay.

Depending upon water levels in the section of Langley Bay open to Lake Athabasca and the section cutoff from the larger portion of Langley Bay, flow from Gunnar Central may flow into "cutoff" Langley Bay or directly into the open portion of Langley Bay. During this study when observations could be made after spring melt (June - August, 1985) flow from Gunnar Central appeared to be channelled direct to Langley Bay. Water from the cutoff section of Langley Bay can exchange with the open section of Langley Bay to a limited degree, dependent upon the water level of Lake Athabasca. The open section of Langley Bay actively exchanges with Lake Athabasca.

In order to estimate the surface runoff from Gunnar Main tailings area and a small beaver pond located just below it, a weir was partially constructed in December 1985 in the bedrock valley between Gunnar Main and Gunnar Central. Final construction was completed in March. Weir instrumentation was completed in late April, prior to spring melt.

Approximately 60 percent of the total runoff measured during the field project (until the end of August 1986), occurred during the first week of May. The flow pattern shows a very rapid runoff response to snow melt in early May. During the slow lowering of the water table in late May and June, the runoff pattern is relatively constant and at a low rate. During a two day period in mid June, a rainfall event produced a rapid runoff response suggesting that the tailings became more fully saturated for this brief period. Intermittent rainfall activity in July and August produced only slight changes in runoff as most of this rain soaked into the tailings. Where runoff did occur, the hydraulic response was very rapid.

In addition to surface runoff data, flow-proportional, water samples were collected at the weir for chemical analysis. The water is dominated chemically by calcium, magnesium, sodium and sulphate and has a neutral pH. The activity of Ra-226 and Th-230 is of the order of 0.5-1 Bq/L while the concentration of uranium is of the order of 0.2-0.4 mg/L. The chemistry of this water after the initial snow melt reflects to a large degree, a hydraulic displacement of tailings porewater with some rain water dilution.

Although water quality runoff from Gunnar Central to Langley Bay was not measured as part of this study, samples collected by Environment Canada showed that similar to runoff from Gunnar Main, runoff from Gunnar Central during the summer reflects a hydraulic displacement of tailings porewater.

Concentrations of tailings constituents are higher in the cutoff section of Langley Bay then in the open section. This results partly from the source of radionuclides being different, but mainly from the exchange of Lake Athabasca water with that of Langley Bay. A method for assessing the amount of exchange between Langley Bay and Lake Athabasca are given in this report. The bathymetry of Langley Bay and Cutoff Langley Bay were synthesized from field measurements in order that volumetric calculations and water exchange rates with Lake Athabasca could be calculated for future modelling work. Despite the restricted channel leading to Lake Athabasca, the exchange rates are estimated to be the dominant factor influencing the concentrations of contaminants in Langley Bay when account is taken of contaminant transport into Langley Bay.

6.1 Surface Water Hydrological Studies

6.1.1 General

Evaluation of surface runoff from the Gunnar tailings management area was recognized as an important component of the field study requiring the collection of continuous discharge data on well-defined streams. Past experience has shown that such continuous data are essential for characterizing runoff from small catchments. Small watersheds are subjected to runoff which has a rapid rate of increase and rapid rate of decrease after rainfall events. Critical information is lost if flow rates are measured once per day on such watersheds. But streamflow data are rarely collected in small watersheds.

The Gunnar tailings area was initially perceived to have less rapid runoff rates than that of an equivalent-sized watershed because the porous nature of the tailings and the relatively flat slopes would absorb and hence buffer the runoff events. However, the patterns observed still indicate a relative quick increase and decrease of runoff rate after a rainfall event.

An initial analysis of the physical features and hydrological characteristics of the site was made using areal photographs and stereoglasses. The stereoglasses give a three-dimensional view of the site. The analysis indicated that there were three possible sites at which a continuous water level recorder could be positioned: (i) at a point downstream of Gunnar Main (ultimately chosen as the gauge site) where there is a sharp fall in the stream and bedrock; (ii) 100 m downstream of Gunnar central; and (iii) possibly seepage through the coffer dam. On site inspection in the early winter (Dec. 1984) indicated that the site downstream of Gunnar Main was the site with suitable topography for constructing a weir.

Due to the remoteness of the site, it was decided to use an automatic sampler for obtaining water sample for chemical analysis. A combination water flow-automatic sampler made by ISCO was selected for this purpose. This sampler uses an air bubbler system to measure the water elevation and a water sampler which draws water from the stream into a sample bottle. The water sampler can be controlled to draw water on a flow-basis or on a time-interval basis; in this study the flow-basis was used.

A continuous recording gauge requires housing to shelter the instruments, a weir in the stream, and pressure tubing connecting the stream to the instrument. This is best constructed during non-frozen conditions (between June-Sept). This insures that the weir plate is well-bedded and prevents seepage around it. Due to the late project starting date, this was not possible. According, the initial strategy was to build the housing and weir etc. in December and then place the instrumentation in the housing in late winter (April). Because of a large snowfall in November 1984, the strategy was modified because water was flowing in the stream during the December field campaign, precluding sealing the weir plate to bedrock. The revised strategy involved building as much of the weir and housing as possible in December, completing the work in March, and instrumenting the gauge just prior to spring runoff.

6.1.2 Instrumentation for Surface Water Runoff

A BEAK field crew visited the study area from December 3 to 10, 1984. At that time final site selection was made for a flow measuring installation. The site is indicated on Figure 6.1.1, along with photographs of the weir during ice conditions. The catchment area is about 102 hectares at this location, including the Gunnar Main Tailings pond.

The weir was located in a crevice formed by a fault line in the bedrock and thus provided an ideal configuration. Streamflow at this site is naturally constricted by the bedrock on both sides and the bottom of the natural channel with the underlying narrow crevice being naturally sealed with glacial clay. It is highly unlikely that a significant portion of the runoff could by-pass this site as groundwater flow due to the integrity of the bedrock in the area and the relatively narrow width of the drainage area at this site. The sides of the crevice rise steeply several meters to heights of land at the edge of the drainage area on both sides (see Figure 6.1.1b).

A 1 metre rectangular weir was built into the channel crevice during the December Field program. The weir was bolted into the bedrock at about 10 places along the sides and bottom through 4" by 4" pressure treated timbers. Figure 6.1.2 illustrates the final configuration. The weir face was made of 0.5 inch plywood. The invert of the weir was fitted with a galvinized metal strip to provide a clean sharp edge. Tar was used to create a seal between the rock and the weir. A 1 metre stage plate was fixed to the upstream side of the weir. The weir invert was about 10 to 25 cm above the natural channel bottom.

A shelter for instruments was placed on beams spanning the channel crevice about 2 metres downstream of the weir and 1.5 m vertically above the weir invert. The shelter was insulated and was equipped with a propane heater. No further instrumentation was added during this time period as significant runoff was not expected for several months. Some runoff was observed in December in the bottom part of the crevice after the snow and ice had been cleared. The runoff rate was estimated at less than 0.5 litres/second. When the ice was chipped away from the bottom of the crevice, the runoff flowed under the weir at its deepest spot. The weir was not sealed at this spot because suitable sealant was not available on site during this campaign.

During the March 16 to 20, 1985 field campaign it was observed that the flowing water had filled the entire crevice with ice to a depth of about 1 metre upstream and downstream of the weir. This ice also covered the invert of the weir to a depth of approximately 0.5 m. The ice appeared to result from water in the stream flowing over the weir in December and freezing until it covered the weir to a depth of 0.5 m. This ice was removed at the weir and the hole at the bottom of the weir was sealed with bentonite chips. No flowing water was encountered at this time.

From April 30 to May 3 a second field trip to the weir site was undertaken to install flow measuring and recording instruments and water sampling equipment. The ice in the crevice was unchanged from the March field trip. An ISCO model 1670 bubbler type flow meter was installed along with an ISCO 2100 sequential water sampler. Both instruments were powered by 2, 12-volt golf cart batteries connected in parallel. The batteries were kept nearly-fully charged with a solar power panel mounted on a nearby hill. A local field technician was trained to make weir observations and change sample bottles.

On April 30, following a period of extended warm temperatures and sunlight, runoff began to flow over the ice in the crevice upstream of the weir. Within 3 days the flowing water had completely eroded the ice in the crevice and started to flow in the natural channel. The snowpack decreased significantly during this period. Instrumentation was complete on May 1.

The weir was left unattended after the start of spring melt until the completion of spring melt. Attempts were made to reach the weir in mid-to-late May by airplane, but conditions in the lake (ice for a float plane) and on the landing strip (soft land) where inappropriate for landing during this period.

The local observer was able to land on May 29 (see Table 6.1.1). Inspection of the weir site revealed (i) that only 2, 1L sample bottles were full, whereas several should have been full, and (ii) that the pool behind the weir was essentially empty. Water was flowing under the weir plate through a hole between the bottom of the weir plate and bedrock. Further attempts by the local observer to seal the hole (see Table 6.1.1) and to recalibrate the flow instrument were not successful. The hole was finally repaired on June 12. The flow meter was recalibrated using a stopwatch and bucket.

Analysis of the observations made by the local field technician and of the flow recorder chart paper indicated that the leak developed on May 6 but that the majority of spring melt and runoff had occurred before the leak developed (see Section 6.1.3). Accordingly, flow measurements are estimated for the period May 6 to May 29. For the period May 29 to June 12, flows were measured on the days that the local observer was present using a bucket and stopwatch at a downstream constriction. The flow rates were fairly constant.

The leak appears to have developed in a crevice just below the weir plate where residual ice must have existed after grouting in March - April. The development of the leak poses significant problems for estimating flow, but its possibility was forseen at the time of project start-up. The project started under winter conditions and because the project was for one hydrological cycle, weir installation under winter conditions was necessitated in order to catch spring runoff. Under such conditions, the stability of grouting can not be guaranteed. Even in longer terms studies, one to two hydrological years are required before all significant problems associated with gauging stations are elimintated.

During the June 22 to 24 field campaign, the weir was modified from a 1 metre width to 0.1 metres to increase the accuracy of recording the low flows observed at this time. The flow meter was recalibrated using a theoretical curve and a one-point calibration (measured flow on one day using a stop watch and bucket).

Also during the June 22-24 field campaign, it was observed that a beaver dam existed some 0.1 km above the weir which had ponded water. This beaver pond was the source of much of the runoff during low flow periods of late summer. It is not clear whether the beaver dam was built prior to freeze up in 1984, or whether it was constructed after spring melt but before the first field trip in 1985.

The instrumentation at the weir was checked during the July 26 to 30 field campaigns and recalibrated.

On August 4 the chart paper ripped off the spool, preventing the recording of flow data. However, the sampler continued to sample stream flow and cumulative flow was totalized on a separate channel. Also during August, the solar panel was mysteriously disconnected allowing the batteries to discharge.

The instrumentation was removed on August 27 during the August field trip. The weir and shelter were left intact.

6.1.3 Results of Surface Water Monitoring

Flow rates for the period May 1 to August 4 were measured and recorded with the ISCO flow meter. For the period of the leak (May 6 to May 29), and of missing records (April 30 to May 1, and August 4 to 31), flow rates were estimated based upon streamflow regression coefficients. This approach is particularly useful for estimating flow after significant precipitation events. In this approach, it is assumed that the runoff rate (Q) at any time (t) after surface runoff, has ceased, follows the following relationship: (Viessman et al, 1972).

$$Q(t) = Q_q \exp(-t/k) \tag{6.1}$$

where Q_q is the flow rate at the start of the regression and k is the recession constant. Consistent regression coefficients were obtained by fitting Equation 6.1 to measured flow rates for several runoff events.

Table 6.1.2 lists the observed and estimated flow rates along with cumulative runoff and precipitation over the study period. Note that the majority of runoff occurs in the first five days following a precipitation event. Modest flow rate increases follow the large rainfall events (i.e. June 13 to 18; and July 20-24).

Figure 6.2.3 and 6.2.4 present this same information in graphical form.

Measured flow rates are relatively accurate as the ISCO flow meter can discern water level changes of ± 1 mm. At high flow rates this represents a measurement error of approximately ± 5%. At very low flow rates the error may be as high as 25%. Flow rates for individual hydrographics estimated by regression are judged to be within 100% of the actual value.

It is not known for sure how much streamflow is affected by slight precipitation events (e.g. LT 5mm). There were 5 significant precipitation events but flow rates for two of these (i.e., August 5-6, August 25) were estimated. Undoubtedly these events have a very minor, short term effect on runoff because they occurred late in the summer when the groundwater table was low.

Total cumulative runoff is judged to be subject to an error of about ± 15%. This error estimate is low, relative to the other estimates provided above, because the portion of the total flow, not measured, is small and because most of the water volume occurred at high rates when the equipment accuracy is good. For this error estimate, the associated error bars are illustrated in Figure 6.1.3.

6.2 Snow Cover and Dust Evaluation

6.2.1 Introduction

During the March 1985 campaign a series of snow cores were taken across four grid lines on Gunnar Main. These cores were taken to provide an estimate of snow cover on the tailings for the calculation of hydrological balance and to obtain an estimate of the amount of wind generated dust that would be entrained in the snow during the winter.

6.2.2 Methodology

(a) Snow Cover Evaluation

The rectangular grid level laid out by BBT (see Figure 6.2.1) was used as a basis for locating snow core sample locations. Stakes had been placed at 25m intervals parallel and perpendicular to the long axis of the tailings. At an undisturbed site near the stake, a 4.4 cm diameter plexiglass tube was driven vertically down to the tailings surface, and the depth of snow cover was recorded. At snow cover depths of 50 cm or less, multiple cores were taken to enhance accuracy. If an ice layer was encountered prior to the tailings surface, this was also noted. The snow was then extruded into labelled Whirl-pak bags.

Upon return to field housing in Uranium City, samples were thawed and poured into a graduated cylinder. Single site multiple cores were averaged together. Seventy eight sites were sampled on March 21st. Snow depths were averaged and combined to produce a total snow cover volume for the tailings pile. Values of average water volume per unit snow depth were used to determine the total equivalent water volume as snow.

(b) Dust Entrainment

Two typical areas, where the tailings surface had been exposed by wind, were chosen for dust sampling and designated Knoll 1 (K1) and Knoll 2 (K2) (see Figure 6.2.1). Samples were taken from snow adjacent to the exposed knolls using a north/south, east/west grid and the centre of the knoll as the grid cross point. Cores were taken at 5 metre intervals on the axes using a 20 cm diameter thin wall pipe and depths of snow in the core recorded. The cores were bagged and transported to the Toronto Laboratory.

In the laboratory, a subsample of the snow cores were taken and the amount of total suspended particulate (dust) measured by filtering the water through a 0.45 um filter. The dust samples were further analyzed using scanning electron microscopey and mean grain size and shape determined. These results are reported in Volume 3: Atmospheric Studies.

6.2.3 Results

The depth of snow in the different cores and the water equivalent is given in Table 6.2.1. The weight of dust in each core is given in atmospheric section of this report.

6.2.4 Relationship of Snow Cover to Runoff

Total water equivalent in the snowpac on April 30 is estimated to be 12.9 cm. Total rainfall during the flow measurement period was 14.2 cm for a total of 27.2 of water. Total runoff was estimated at 45400 m^3. This is equivalent to 4.47 cm over the drainage area. Therefore, the runoff yield is about 16%. Evaporation, and transpiration are the other significant pathways for loss of water from the system. Groundwater losses from the basin because of the tight clay underlying the Gunnar main basin and the tight bedrock in the area is estimated to be a very small percentage of the surface water runoff.

6.3 Surface Water Hydrology of Embayments at Gunnar

6.3.1 Introduction

Of all the tailings area in Canada, the Gunnar site is one which has a large potential for impacting surface water quality due to the placement of tailings in Langley Bay. A sufficient volume of tailings was discharged, to cut Langley Bay into two portions: one ('Open' Langley Bay) which connects to Lake Athabasca as an embayment, and one portion which is essentially cut off from the open bay (Cutoff Langley). The cutoff portion is connected to open Langley Bay by a narrow channel of 1-2 m cross-section. Inspection of the channel on two field trips (June 20-26, August 22-24) indicated that there were no apparent water level variations along the channel as indicated by currents or ripples, suggesting that the water level of cutoff Langley is essentially the same as for Langley Bay at the time of this study.

The objective of this section is to summarize studies which allow a description of the hydrological flow pathways in these two surface water systems.

6.3.2 Methods

The major pathways of concern and possible methods for evaluating them are summarized in Table 6.3.1. It was not possible to measure local drainage into Cutoff Langley Bay or into Langley Bay in this study. It is suggested that a runoff coefficient and drainage area delineation could be used to estimate these items. Rainfall directly to the water body can be estimated using the measured rainfall data from the Gunnar Main Meteorological Station and measurements from long term sites. Evaporation could be estimated using the meteorological station data, suitable formula, and a heat budget approach.

Discharge from Gunnar Central was not measured because a suitable gauging site was not identified in the early site reconnaissance. The discharge volume from Gunnar Main could be estimated using measurements made at the gauging station and using a unit runoff coefficient approach to estimate runoff in the remainder of the watershed between the gauging station and the Gunnar Main outlet.

Alternatively, runoff from these ungauged areas (local drainage to Langley Bay, Cutoff Langley, and the catchment of the Gunnar Central) could be estimated using a suitable watershed hydrology model. Necessary data for such an effort include soils, slopes, groundwater levels etc. The data of this project should be adequate for the Gunnar Main area, but may not be for the other drainage areas. This might require some additional physical measurements in these drainage areas, although the tight character of the bedrock and the small amounts of surficial tills would minimize the extent of measurements required.

Flow between Cutoff Langley Bay and Langley Bay, and between Langley Bay and Lake Athabasca could be estimated using current meters, measurements of variations in the water surface elevation at short time scales, and/or a dissolved substance budget. Evaluation of the hydraulic characteristics of the channels connecting the water bodies indicated that the use of current meters was beyond the scope of this project. Accordingly, efforts concentrated upon measuring water level variations and evaluating th concepts for computing exchanges between the water bodies using a dissolved substance budget.

One water level recorder was installed in Langley Bay and one in Cutoff Langley Bay on June 24, 1985. The recorder (see Figure 6.3.3) was positioned on a rectangular platform located approximately 1 m above the water surface and in 0.5 m of water. The platform was supported at each corner by a steel tube driven into the tailings by a fence-post pounder. The posts were enclosed with a Canadian Tire special tarpaulin to create a water well. Because the tarpaulin did not reach the bottom of the water, the water in the well was in equilibrium with that outside it.

The water level recorder, a Steven's type A, was mounted on the platform. A float on the water was connected to the recording pen by a stainless steel wire which went over the level-indicator drive wheel. The drive wheel is connected by suitable gearing to the water level recording pen.

6.3.3 Results

(a) Water Level Recorder

A typical result from the water level recorder for Langley Bay is given in Figure 6.3.1a for the period July 14 to 23 in Langley Bay. The gear ratio was set as direct - hence, one 0.1 m deflection on the chart paper reflects a 0.1 m deflection of the water level. From July 14th to July 20th, the water level is fairly level with pertubations on July 14th and July 20th. On July 20th, the water level shows an unusual immediate jump of 3 cm which is sustained for several days. Inspection of typical water level records for Lake Athabasca at Crockingstone Point shows that such an instantaneous jump are not apparent. Accordingly, it is concluded that the jump on July 20th resulted from the stainless steel wire jumping off of the drive wheel and inertial forces causing the drive wheel to rotate until the stainless steel wire locked in the next notch.

Inspection of the whole water level recorder record indicates that there were two such jumps, upwards and one jump, downward, during July on Langley Bay. This recorder ceased to work 2 days after the July 27/85 inspection due to a circuit malfunction.

Inspection of the cutoff Langley Bay chart shows that the water level was flat for the whole period of June 26 to August 28 except for one jump in the record on July 4 (see Figure 6.3.1b). The record shows a change of elevation approximately 0.5 cm over the period of July 4 to August 28.

Evaluation of the water level data indicates that it is not feasible to estimate exchanges flows with confidence between Langley Bay and Cutoff Langley, and between Langley Bay and Lake Athabasca from these data.

(b) Solids Budget Approach

Another method for estimating exchange rates is the use of a dissolved solids budget. This approach is now illustrated using historical data. The data gathered in this report could be worked up similarly.

The Gunnar site may be envisaged as sketched in Figure 6.3.2. The symbols Q_1, Q_2 and Q_3 describe successive flows (unidirectional) from Gunnar Main through to Lake Athabasca. Q_1 describes outflow from Gunnar Main, Q_2 flow from Gunnar Central, and Q_3 flow from Langley Bay to Lake Athabasca. A separate hydrological flow path would need to be added to describe flow from Cutoff Langley to Langley Bay. Conceptually, the magnitude of Q_3 is due mainly to Q_1 and to local runoff from the Langley Bay watershed. Local runoff from Gunnar Central and Langley Bay watersheds will be substantially larger than Q_1. But, most of the mass transport associated with Q_3 will be due to Q_1. Also most of the mass transport associated with Q_2 is derived from Q_1.

In addition to unidirectional flows, a hydrologic pathway labelled E (exchange flow) is indicated, as occuring between Langley Bay and Lake Athabasca. This results from the following. During a strong wind, the lake level near the Bay mouth may rise, inducing a current from the lake into the Bay. After relaxation of the wind (e.g., perhaps one hour later), the lake level will fall; because the Bay is now higher than the lake, water will flow back from the Bay into the lake. In addition, nearshore currents may enter on one side of the mouth and leave on the other side.

When viewed on an hourly basis, the current movements between the Lake and Bay are vectors, being unidirectional. But when viewed over a longer averaging time, a simultaneous exchange of a certain volume of water occurs. If, for example, 1,000 m^3 are exchanged daily, E has a value of 1,000 m^3/d. Physically, one can conceptualize a 1,000 m^3 of Lake Athabasca water moving to the Bay accompanied by a simultaneous movement of 1,000 m^3 of Langley Bay water to the lake. Hence, if the concentration of sulfate, TDS etc., is higher in the Bay, one can look at exchange flows as being an extra dilutant of Bay water quality.

An overview of TDS and historical conductivity data is given in Table 6.3 for the stream discharging from Gunnar Main (Q_1), for Langley Bay and for Lake Athabasca. Historical TDS data is negligible. For cutoff-Langley and Langley Bay, TDS approximately equals 0.7 of conductivity. For other surface water bodies (e.g., Lake Ontario, Hamilton Harbour), TDS = 0.65 of conductivity. Hence, the Gunnar hydrological system, has relationships similar to those of other water bodies, although there is no reason to expect that all water bodies would have similar relationships because conductance is a function of the ions present, as well as their concentration. Different ions (e.g., compare H^+ to

Fe^{3+}) make different contributions to conductance. The TDS value in the weir sample is probably too high. Previous work shows that the solid formed in the TDS test probably contains waters of hydration within a $MgSO_4$-$CaSO_4$ matrix. If the TDS value is 20% too high, then TDS equals approximately 0.8 of conductivity.

The data of Table 6.3.3 shows that the chemistry of runoff at the weir is diluted substantially in Langley Bay by an excess of 1:50. Concentrations in Langley Bay are close to, but larger than those of Lake Athabasca. If there was no mixing between Langley Bay and Lake Athabasca, then the conductivity or concentration of TDS in Langley Bay should be close to that of the stream leaving Gunnar main. The concentration of ions in Langley Bay would be lower than that of the weir due to dilution by catchment runoff, but would not be diluted by more than 1:50. Accordingly, mixing between the lake and the bay has a substantial effect upon Bay water quality.

Data such as conductance can be used to obtain estimates of exchange flow provided the parameters are conservative. A conservative parameter is one which does not have significant losses due to sediment absorption of radioactive decay. A method for calculating E is now given.

Calculations of Exchange Flow

A model for exchange flow has been formulated for a more complex environment (two layer flow between Lake Ontario and Hamilton Harbour) (Klapwijk, 1984). Its simplification gives the steady state equation:

$$O = Q_3C_{IN} - Q_3C + E\,(C_L - C)$$

where C_{IN} = concentration in inflow to Langley Bay
C = concentration in Langley Bay
C_L = Lake Athabasca Concentration

This reduced to:

$$E = BQ$$

where $$B = \frac{C_{IN} - C}{C - C_L}$$

Estimates of B are given in Table 6.3.2b assuming that the conductance values given in Table 6.3.2a for the Gunnar Main outflow are not substantially diluted before the outflow becomes inflow to Langley Bay. The value of $B = 200$ is calculated from the observed values of $C_{IN} = 9{,}000$, $C = 115$, and $C_L = 70$.

Other substances can also be used to estimate B. These substances include calcium, sodium, magnesium, sulphate and potassium. It is possible that calcium and sulphate may not be completely conservative, but they should be approximately conservative. The range of estimates for B (130 to 220) are calculated for the range of measured conduction values given in Table 6.5a. But if the range of field conduction values is the second set given in Table 1a, then the range of B is 120-450. Using observations for these substances, the range of values for B is 80-850 (see Table 6.3.2b).

Some conservative substances can not be used to estimate values for B because of the properties of the data and the magnitude of the values involved. Inspection of Equation (3) shows that the magnitude of B is strongly influenced by the difference: $C_L - C$. For potassium, for example, $C_L = 0.7$ and $C = 0.8$. But if $C = 0.75$, then a value for B of 50 is inferred. If the measurement for C of potassium is actually 0.65, then B has a negative value, an impossibility.

Potassium is judged to be a border line candidate for use in evaluating B. Because of their low concentration, other substances such as alkalinity and chloride are judged to be inappropriate because the concentration difference between Langley Bay (C) and the lake (C_L) is too small, to give an accurate estimate of B. In fact, historical values for alkalinity and chloride in Lake Athabasca are often higher than those for Langley Bay. It is plausible that the analytical and sampling techniques were not capable of distinguishing differences at low values.

These calculations point out the following requirements for selecting a conservative parameter for estimating B:

1. Large differences between C_L and C provide confidence in the value of obtained.
2. The analytical technique used to measure the parameter should have the appropriate sensitivity (e.g., detection limit, accuracy).

The estimates of B given in Table 1(b) suggest an order of magnitude range, from the same data sets. This is not plausible. The range must result from analytical and sampling uncertainties and environmental variation. The relative weight of these two possibilities is unclear.

Calculations of E (m^3/yr) are also given in Table 6.3.2b, assuming that the average annual value of Q_3 is 2×10^4 m^3/yr. This value for Q_3 assumes that $Q_1 = Q_3$, and that 10 cm of precipitation infiltrate annually into 20 ha of tailings and then subsequently leaves as surface runoff. Additional runoff from the Langley Bay drainage basin would not affect the estimate of E, because the additional runoff would only dilute the rate of mass export from the tailings but not change it. Increased runoff would result in an increased value for Q_3, but a commensurate decrease in the value of B.

B can be thought of physically, as a scaling factor, between E and Q. The values for E and B show that exchange dilutes inflow concentrations by somewhere between 1:50 and 1:1000. Hence, exchange flows are the hydrological pathway which dominates the dynamics and water quality of Langley Bay.

Morphometry of Langley Bay and Cutoff Langley

Depth contours for Langley Bay and Cutoff Langley are given in Figure 6.3.6. Values for surface area, volume, and mean depth are given in Table 6.3.4. These data were developed by using a depth sounding instrument on the water bodies on June 24, 1985.

6.4 Surface Water Chemical Studies

6.4.1 Introduction

Water samples were collected from the gauging station downstream of Gunnar Main on a regular basis by the automatic sampler and from other surface water bodies and streams during field campaigns. This appendix describes sampling procedures, and gives analytical and QA/QC results. Data are given in Tables 6.4.1 to 6.4.16.

6.4.2 Methods

This section presents the methods used for collecting surface water samples at the Gunnar site, shipping and subsequent chemical analyses.

Field Method - Sampling

Water samples were withdrawn from the stream below Gunnar Main by the automatic sampler on a flow-proportional basis. The meter was set to pump approximately 150 ml of stream water into a 1-L sample bottle when a specific volume of water passed the weir. When six injections of 150 ml into a sample bottle were completed, the injection tube changed to an empty sample bottle. The specific volume of water which was present was changed during each campaign to reflect the expected runoff rate.

A set of samples was initially collected by a local field technician during the spring period, and thereafter by BEAK personnel during each field campaign. As indicated above and in Table 6.1.1, only two samples were collected from the spring runoff due to failure of the weir. For the period, June 6 to 22, spot samples were obtained when personnel were present for weir maintainance operations. Samples were retrieved from the sample tray for July during the July 26-30 campaigns, and for August during the August 25-29 campaigns. The July samples covered the whole July period, while the August samples covered only part of the August period due to failure of the power supply to the automatic sampler.

Sample retrieval during the July and August campaigns involved pouring the water sample from the ISCO sample bottle into a plastic bottle with a tight cap and then carrying the sample out by back-pack to a plane which flew field staff back to Uranium City. The ISCO sample bottle could not be used for transport because the caps were not tight. Care had to be used in pouring water out because there were precipitates present in the sample bottles. They were removed from the ISCO sample bottle by pouring out most of the water and then using a swirling motion to suspend the precipitates. Some sample which had been poured out was poured back in and then repoured out again to make sure that all precipitates were removed. This washing procedure was used twice. Inspection showed that there were no residual precipitates in the bottles.

An alternative sampling strategy would have involved addition of nitric acid to the ISCO sample bottle before water was pumped into it. This strategy was not used because we desired to analyse for anions and cations on the same water sample as that used for radionuclide analyses.

At Uranium City, several bottles were mixed, subdivided for radionuclide, cation, anion and nutrient analysis and appropriately preserved. Samples for radionuclide and cation analysis were preserved with nitric acid while samples for nutrients were preserved with sulphuric acid. Samples for general parameters (alkalinity, pH, conductivity, turbidity) and for major anions (by IC scan) were left unpreserved.

An assessment of the nature of the chemical precipitates was made. The precipitates were granular in texture, less than 1 mm in size and appeared brown in colour suggesting initially that they might result from the coagulation of organics. The study involved using one or two unpreserved bottles, filtering, and measuring the content of the precipitate by ICP and DCP. The assessment was intended to be qualitative, rather than quantitative. The results indicated that the floc was primarily composed of manganese with no significant organic carbon content. There was no sulphate measureable on the precipitate. It was concluded that the floc resulted from the slow oxidation of manganese which precipitates as a hydrous manganese oxide and which also takes some iron out of solution. It probably results from manganese transport from the tailings in a soluble or colloidal form and the formation of a precipitate in the sample bottle.

A small error in conductivity measurements would be introduced because of precipitate formation. The error for dissolved solids would be minimal because TDS was calculated upon the total water sample, assuming that there was no significant quantity of suspended solids before precipitate formation (see Section 6.4.4). The effect on the cation-anion balances would be small because manganese does not make a substantial contribution to electroneutrality.

The sample preservation procedures used are those suggested by the U.S. EPA (1974) and Chiu and Dean (1984) with necessary exceptions. The preservation procedures for normal (pH 7 to 8) surface waters are as follows. For acidity, and alkalinity it is recommended that samples be kept cool (4°C) for a maximum holding time of one day. For pH, on-site determination is recommended with a holding time of up to six hours. For nutrient parameters, it is recommended that they be preserved with sulphuric acid to pH less than 2, kept cool, and a holding time of seven days.

For sulphate, it is recommended that the sample be kept cool at 4^oC with a holding time of one week. For specific conductance, keep cool at 4^oC with 24-hour holding time. For metals, a HNO_3 preservative with a holding time of up to six months is recommended; the preservative should lower the pH to less than 2.

These procedures were generally used in this study, with exceptions. No sample analyses (e.g., pH, alkalinity, conductivity) were conducted in the field because the samples were a few hours to a few weeks old after retrieval from the automatic sampler. The requirements for pH, acidity/alkalinity and sulphate could not be met because of holding times in the sampler between field campaigns.

Laboratory methods for chemical analyses used by the different laboratories are detailed in Volume 2. Most of the cations were measured by DCP by BEAK. Anions were measured by ion chromatograph by BEAK. Samples for analyses by the Check laboratory were analyzed by Barringer Magenta of Mississauga. Radionuclide analyses were measured by Monenco Analytical Laboratories, with check samples measured by Chemex and Saskatchewan Research Council.

6.4.3 Results

This section describes the analytical results and the QA/QC results.

Analytical Results

Analytical results are given in the following tables:

Table No.

6.4.1	(a)	Gunnar Surface Water - Weir (Dec. - Apr.)
	(b)	Gunnar Surface Water - Weir (May. - Jun.)
	(c)	Gunnar Surface Water - Weir (Aug. - Sep.)

6.4.2	Gunnar Surface Water - Cutoff Langley Bay
6.4.3	Gunnar Surface Water - Langley Bay
6.4.4	Gunnar Surface Water - Lake Athabasca
6.4.5	Gunnar Surface Water - Snow Samples
6.4.6	Gunnar Surface Water - Airport Road
6.4.7	Gunnar Surface Water - Central Main
6.4.8	Gunnar Surface Water - Zemel Creek
6.4.9	Gunnar Surface Water - Other Occasional Spots

Analytical results which examined the nature of a chemical precipitate which formed in unpreserved sample bottles of water from the weir are given in the following tables:

Table No.

6.4.10	(a)	Major Element Analysis of June 6 Precipitate.
	(b)	Radionuclide Analyses of June 6 Precipitate.

Quality Assurance Results

Three forms of quality assurance results have been obtained. Cation-anion balances were made for major element analyses for most surface water sample. These results are given in Tables 6.4.1 to 6.4.9. Measurements made by two laboratories on the same sample, split before shipment, give an interlaboratory comparison. An assessment of the repeatability of the same laboratory was made by splitting a sample and submitting it to the laboratory as two separate samples. These results are given in the following tables:

Table No.

6.4.11	Interlaboratory Comparison for Radionuclide (April-May)
6.4.12	Quality Assurance Monitoring of Radionuclide Parameters for July-Aug. Period
6.4.13	Interlaboratory Comparison and Repeatability Comparison for Non-radionuclide Parameters for Gunnar

As well, QA results for surface water samples from another NUTP project are included, as the total picture from both data sets influence the inferences of this project. The data are given in:

Table No.		
6.4.14	(a)	Radionuclide Laboratory Comparison for July for Lacnor
	(b)	Radionuclide Laboratory Comparison for October for Lacnor
6.4.15	(a)	Blind Replicate for Radionuclide for July for Monenco for Lacnor Sample
	(b)	Blind Replicate for Radionuclide for October for Monenco for Lacnor Sample
6.4.16	(a)	Interlaboratory Comparison of Non-Radionuclide Parameters for Lacnor - April 15
	(b)	Interlaboratory Comparison of Non-Radionuclide Parameters for Lacnor - April 29
	(c)	Interlaboratory Comparison of Non-Radionuclide Parameters for Lacnor - July 19

Analyses of Results

A descriptive presentation of the chemistry of the surface streams is given in the main body. The discussion here is limited to making a few observations upon the results of the quality assurance program.

Cation-Anion Balance

The ions, calcium, magnesium, sodium, sulphate, bicarbonate and chloride generally make the largest contribution to the charge balance for tailings runoff. These ions also make up most of the change balance for Cutoff Langley Bay, for Langley Bay, and Lake Athabasca. Potassium is also substantial in Lake Athabasca. For these components, the electrical charge on cations was compared to that of anions. The total cation charge varies from being 6% larger to 6% smaller than the total anion charge for most water samples except for one Lake Athabasca sample where the difference is 15%.

These calculations of charge balance have ignored the hydrolysis of ions such as aluminum and iron species, and the formation of sulphate and chloride complexes with calcium and magnesium. The hydrolysis of aluminum and iron will have a negligible effect on the charge balance because these ions do not make a significant contributions to the charge balance. Formation of sulphate or chloride complexes will not effect the change balance calculations provided that only one anion complexes with a cation. This is true of magnesium and calcium complexes of sulphate while chloride complexes of the major cations are not significant in the pH 6-8 range.

One other possible influence upon cation anion balances is the formation of a chemical precipitate in the water from the weir. The nature of the precipitate is discussed below. It is concluded that this precipitate is mainly a hydrous manganese oxide incorporating some iron. This precipitate would have a minor effect upon the cation-anion balance because neither iron nor manganese make a substantial contribution to the anion-cation balance.

Quality Assurance Monitoring for Radionuclide Parameters

Interlaboratory comparisons (see Table 6.4.11 and 6.4.12) consisted of asking three laboratories to analyze samples - Monenco as the prime laboratory, and SRC as the main check laboratory. Because an initial interlaboratory comparison which used three laboratories (Chemex as the third) showed substantial variation (Table 6.4.11a), for some radionuclides for Lacnor, the use of two check laboratories was continued in a later comparison (Table 6.4.14) for Lacnor.

Values for uranium and Th-230 measured by the different laboratories are quite close (10%) (see Table 6.4.11 and 6.4.12). Values for Ra-226 are reasonably close for the Cutoff Langley sample but further apart for the weir sample.

However, when the interlaboratory comparison for the April-May period for surface water samples from both the Gunnar Tailings Management Area and the Lacnor Tailings Management Area is composited, a slightly different picture emerged. Uranium values were as consistent as for Gunnar alone. As well, Th-230 values were quite consistent.

But values for Ra-226, Th-226, Th-232 and Th-228 showed up to an eight-fold difference in the interlaboratory comparison for Lacnor samples (see Table 6.4.11). There is no obvious bias because none of the laboratories are consistently high nor low for Th-232 and Th-228 parameters. Bacause a common tracer is used for all three thorium parameters and because they are measured after the same concentration-precipitation steps, a similar deviation should be observed for Th-230 as for Th-232 and Th-228. Because these results were unsatisfactorily, all results (Table 6.4.11) were tabulated and forwarded to the three laboratories without identifying the name of the other laboratories. They were asked to check for transcription or calculation errors. None were found except for one uranium value. One laboratory (Monenco, - the laboratory with the low values for Ra-226 and Th-232/Th-228 for Lacnor) repeated their analyses for Ra-226 and found the initial results to be satisfactory and hence stood by them. This laboratory also offered some plausible explanations for the differences. The other laboratories suggested reasons for the differences, but did not have sufficient sample to re-analyze their samples.

In subsequent interlaboratory comparisons for Lacnor radionuclides (Table 6.4.14) the values Ra-226 and Th-232/Th-228 were much closer. Hence, the wide range of Table 6.4.14 for Lacnor, while unsatisfactory, remains unexplained. A plausible reason involves differences in the chemical precipitation steps used by the different laboratories and the presence of colloidal-sized precipitates of iron hydroxide in the Lacnor water samples which scavenge radionuclides.

The interlaboratory comparison for Ra-228 showed unsatisfactory results for the first April-May period (Table 6.4.14) with differences of up to ten times for Gunnar and five times for Lacnor. There should be no measureable activity in the Gunnar samples. The high values were subsequently resolved as being erroneous because Monenco thought that they had a higher detection limit than actually occurred. But to be fair, this problem is possibly foreseeable because all the samples of Table 6.4.11 were analyzed in the middle of a group of experiments which contained substantial levels of Ra-228 (greater than 100 Bq/L).

The analysis of a blind replicate by Monenco shows good repeatability for uranium and Th-230 in the July-August period but poorer for Ra-226 for a Gunnar weir sample (Table 6.4.12). A similar degree of repeatability was produced by Monenco for July (Table

6.4.15a) and October (Table 6.4.15b) samples from Lacnor. However, the results also show unsatisfactory detection limits for radionuclides counted by beta spectroscopy for Pb-210 and Ra-228. This is possibly due to:

- o the beta counter having a background count which is approximately 20 times that of alpha spectroscopy, and
- o not using a large enough sample to count.

Quality Assurance for Non-Radionuclide Parameters

The interlaboratory comparison (Barringer-BEAK) in Table 6.4.13 shows that ICP (Barringer) and DCP agree reasonably well with a few exceptions. The laboratories show reasonable agreement for the April samples for Lacnor for major components (Ca, Fe, Al, Si), but good agreement for these major components for the July sample from Lacnor.

For minor cations in the sub-mg/L range, the agreement is also good for some cations (e.g., Ba, Sr), but poor for others. The differences in agreement for these cations results partly from differences in detection limits for parameters such as Mo. In the sub-mg/L level, the DCP appears to give erroneously high results for Cr and Pb for both the Gunnar (Table 6.4.1) and Lacnor surface waters (Table 6.4.14). This is attributed to a possible calcium interference with the DCP instrumentation and has been noted by other DCP users.

A more limited interlaboratory comparison was made for anions and other parameters. The differences between measured sulphate concentrations varies from 4% to 25% for Gunnar and Lacnor. The value for chloride and fluoride by BEAK for the Lacnor samples are approximately double those of Barringer. The nitrate and phosphate parameters are below the detection limit, although the detection limit of Barringer's ion chromatograph is somewhat better than for BEAK. In the anion scan, the high detection limit for nitrate, phosphate and nitrate is caused by tail of the sulphate peak interfering with the nitrate, nitrate and orthophosphate peaks.

One repeatability set of results (Table 6.4.13) shows good agreement for anions, conductivity etc. The laboratory never analyzed the cations at the same time, which prevents an assessment of its repeatability within the same batch of samples.

Discussion of Interlaboratory Comparisons

A comparison of chemical analysis for cations and anions to the measurement of activity of radionuclides suggests that variation between laboratories and within a laboratory is narrower for cations and anions than for radionuclides. But the counting statistics for radionuclide measurement are generally as good as the measurement statistics for cations and anions. The major differences are thought to be due to preparation procedures. Radionuclide measurement of liquid samples involves sample precipitation-concentration-purification steps. The largest source of variability in radionuclide measurements must result from problems in the preparation steps or non-homogeneous precipitation of tracers added.

Interlaboratory comparisons were made in this project as a part of its quality assurance program. The quality assurance program had both clinical and accuracy/precision components. The objective of the chemical component was to provide the reader with the ability to establish that standard procedures and methods were used and to assess the quality of the data. Assessment of data quality may mean the chemical practice of defining accuracy/precision components to the reader. But it is taken herein to include the development of data which can be used by the NUTP for the following objective: to provide a scientifically credible information base upon which decisions can be made, with a known degree of confidence, in establishing reasonable criteria for the protection of the environment, and which can be used to propose practical guidelines for uranium tailings management. The QA program of this report provides information about the potential levels of variability and delves into error associated with chemical analysis.

Cation (IAP/DCP/AAS) or anion measurements, are generally direct. Accordingly, one might expect a more consistent analytical ability. This will, however, occur only when a constituent can be measured free of interferences. Standards for samples are generally based upon pure solutions, or on a set of standards with a known matrix. Evaluating the level of a constituent which has a different matrix (of other constituents) can easily lead to erroneous results. For example, calcium may have an absorption or emission peak at the same place on the spectrum as lead. At certain concentration levels, calcium may interfere by artificially increasing the value of the peak above that caused by Pb. Then, chemical measurement of Pb is either not possible or requires the analyst to choose a secondary wavelength of lead for analyses - such a wavelength may be much less sensitive and/or have its own interferences. Use of the method of standard additions is often required to resolve the proper value for Pb and to determine the degree of interference by calcium. Such an evaluation will be specific to the matrix involved.

The possibility of interferences suggest one course of action for any future work similar to this contract or for any future monitoring by mills. For any water with a new matrix which a lab has not analyzed before, the following procedure should be contracted between the client (government, consultant, or mine) and the laboratory:

(i) Several (4-7) samples should be analyzed by ICP/DCP, by IC, and for pH/alkalinity to identify the major components (cations/anions) and to determine the electroneutrality balance.

(ii) A synthetic set of knowns (3-4) should be made up to contain the major components and their relative proportions in the actual water. Trace substances of concern should also be added in known quantities. These synthetic solutions should then be analyzed to check for the ability of the instrumentation to measure the different cations and anions, and **particularly** to check for interferences for the trace substances.

(iii) The following should be documented: (a) the wavelengths used by the laboratory, (b) the dilutions used, (c) a comparison of the reference values with these actually measured the dilutions used, and (d) the measured values in the synthetic solutions. Such information is difficult to get if it is not documented up front. Such information is needed if an analytical chemist desires to be able to audit the results of a chemical analyses program some years later.

(iv) The development of a synthetic set of knowns should be specifically contracted, as it is not part of a commercial laboratory's normal rate structure. Formation of the synthetic samples could be the responsibility of the laboratory, the client, or an external organization.

(v) The synthetic samples could subsequently be used by the laboratory for internal QC or by the client for external QA auditing.

(vi) The wavelengths, the dilutions etc., used by the laboratory for analyzing field samples, should be formally documented at the time of analyses and available for inspection, rather than being available only upon request (after the fact).

(vii) The ability of a type of instrumentation (DCP or ICP) to measure or not to measure particular cations in a similar matrix should be searched from the literature and documented.

The above procedure represents a suggestion. It results from the fact that it is difficult to determine whether some of the sub-mg/L values are actual or detection limit values because of matrix effects. This is difficult for those of us who were intimately involved with gathering the data but external to the laboratory. It is even more difficult for others not associated with gathering the data. Parameters of interest in this class of sub-mg/L concentration levels include Sr, Ba, and Pb in their role as potential controllers on Ra-226 transport and "toxic" heavy metals such as Cr, Co, and Cu.

Furthermore, because many programs are one-shot efforts (a few months of intensive measurement with a large commitment of professional and economic resource) such procedures designed at the start of a program will help define the ability of laboratories to make measurements. It will also identify the ability of different instrumentation to make chemical measurements of cations and radionuclide concentration within a particular chemical matrix.

This section concludes on a more positive note. As a part of developing the Laboratory Methods Appendix, we requested that the laboratories supply us with additional QC information. This request had not been a part of the original cost between the laboratories and contracting firms. The information included:

(i) replication data made by the laboratory as a part of its QC program;
(ii) comparison of the measurements of standards with the certified values; and
(iii) any other data that the laboratories generated.

One laboratory (BEAK) reported their replication results as a standard practice, while the others provided the values upon request.

All laboratories indicated that they were very pleased by this request and that it allowed them to display their QC program. Two laboratories indicated that the process of trying to retrieve this information gave them insights into better methods for handling, displaying, and retrieving the data and for comparing known values with measured values.

6.4.4 Chemical Precipitation in Weir Waters

Due to the appearance of small, submillimeter diameter, precipitates in the bottom of the weir water sample in Dec-Apr. samples, a special study was undertaken to ascertain the nature of the precipitate. During the June 6th weir maintainance trip by the local field technician, water was collected directly into 10, 1L plastic bottles from the weir and shipped to BEAK's Toronto Laboratory without addition of any preservative.

Inspection of the bottles in the laboratory indicated that each appeared to have the same small quantity of these brownish appearing precipitates. The colour of the precipitate was similar to that of humic and fulvic compounds which give water from bogs and similar areas its brownish colour. Assuming that these substances come from the frog pond, they would have precipitated after coagulation. Due to the basic character the water (pH 7.2 to 7.6), it was thought unlikely that it would be due to aluminum or iron.

One bottle (1-L) was filtered with an acid-washed, glass fiber filter; the filter was split and was analyzed for carbon parameters and by DCP scan. The DCP results for the filter and the filtrate are given in Table 6.4.10a. The Chemical Oxygen Demand (COD) of the filter paper was 2.93 mg/L and the Total Organic Carbon (TOC) was 1.10 mg/L. TOC was not done on the filtrate, but on another sample (see Table 6.4.1b); the TOC was 27 mg/L. Other weir samples from this period have TOC values of 29 and 34 mg/L. Accordingly, it was concluded that some of the precipitate might be carbon, but that this carbon content represented less than 5% of the TOC content of the sample.

The DCP results for the filter paper from the first bottle had some difficulties with Al, Ba, K, Na, and Zn because of the small amount of sample on the filter paper and the relatively high background.

A second bottle (1-L) was filtered with acid washed filters: firstly with a glass fiber filter and secondly with a 0.45 micron filter. A DCP scan was conducted on each filter paper and upon the filtrate. These results, together with chemical analysis of a non filtered sample for June 6 and one for June 8, are given in Table 6.4.10a. For the June 6 sample, the bottle was shaken up and split - one portion was used for conductivity, IC etc. analysis and one portion was acidified to bring the precipitate into solution. For the June 8th sample, it was shaken and acidified to bring the precipitate into solution.

Analysis of the filter data indicate that most parameter values are quite low. The detection limits indicated are lower than normal for some parameters (e.g., Cr, Cd, Co, Mo, etc.) because the data represent the concentration of one liter of water into a few milliliters via filtration. The glass-fiber filter data suggest that the precipitate is composed of manganese, iron, calcium and magnesium. But the calcium and magnesium values are suspect because although they are above the theoretical detection limit, they represent the difference between two numbers (a measured value and a blank) which are similar in magnitude. Furthermore, comparison with data from other projects show that these values represent the values of calcium and magnesium in the filter paper. They are judged not to be real.

Any precipitate which forms will have a particle size distribution which could range in size from colloidal through to submillimeter. A particle sizing analyzer was not available. Rather a smaller filter was used to ascertain what was contained in submicron sized precipitates. The data (see Table 6.4.10a) indicate that only iron and manganese were present in significant fashion in the submicron fraction.

A precipitate will form if solution conditions are super-saturated. Under conditions of the sample bottle, it is expected that a substantial amount of the iron originally in solution should precipitate. Comparison of the filtrate concentrations with that of the total data (filtrate plus filter concentrations), or that of other bottles which were not filtered (June 6 is the direct comparison, June 8 is essentially the same water, but two days later) indicate that manganese is the largest fraction on the filter paper. There is also a substantial portion of iron on the filter paper. For the elements calcium and magnesium, the filter paper values indicated in Table 6.4.10a represent less than a percent of the total. For all other elements, the filter paper had an unsignificant portion of the elements on it.

It is concluded that the precipitate is a hydrous manganese oxide containing some iron as a co-precipitate.

Three, 1-L bottles were filtered with an acid-washed, glass-fiber filter. Each filter paper was analyzed for a different radionuclide parameter. Another set of 1-L bottles, acidified with nitric acid to dissolve the precipitate, were composited after precipitate dissolution and submitted to Monenco as blind replicates. The results are given in Table 6.4.10b. Analytical repeatability is much better for uranium (less than 1% differences) and thorium -230 (less than 5% differences) than for Ra-226 (30% differences). Using the filter paper value to define the concentration in precipitate, the precipitate contains 20% of total U, 80% of the Th-230, and all of the Ra-226 found in solution before formation of the precipitate.

It is concluded that the precipitate is a hydrous manganese oxide, which co-precipitates most of the iron in solution. The data base herein is limited, but it appears that the precipitate also takes all of the Ra-226 and most or all of the Th-230 from solution as a co-precipitate. It would not co-precipitate all Th-230 or Ra-226 because some must be left in solution. But it could co-precipitate most of Ra-226.

6.4.5 Implications of MnO_2 Precipitation for Hydrological Transport Modelling

These results have implications for modelling the Gunnar tailings area which were not forseen in the original program design. The original design assumed that export of cations and radionuclides from Gunnar Main would flow into and out of Gunnar Central without substantial mitigation and then into Langley Bay. The main emphasis in the study was upon Gunnar Main. Because a good weir site was located just downstream of Gunnar Main, but very poor sites downstream of Gunnar Central, the weir was located to monitor export from Gunnar Main. However, we cannot conclude with assurance, how much of the export from Gunnar Main reaches Langley Bay, due to the possibility of manganese precipitation in Gunnar Central and removal of the radionuclides from solution.

The following represents a qualitative evaluation of the probable geochemical-hydrological processes that are occurring between Gunnar Main and Langley Bay. This picture would need to be addressed in a model in order to estimate the discharge of the radionuclides Th-230 and Ra-226 (and probably Pb-210) into Langley Bay.

Transport of radionuclides, manganese and iron occurs from the saturated zone of Gunnar Main. All of the aqueous forms of manganese and probably most of that of iron are in a reduced state during much of the summer under nonspring melt conditions. Most of the iron should be oxidized, precipitated and removed before the water reaches the Frog Pond because the oxidation-precipitation kinetics of iron have a half-time of the order of minutes, at pH 7.2-7.6 in pure solution. But under such conditions, the oxidation precipitation kinetics of manganese (Mn^{2+} to $MnO_2(S)$ are much slower than those of iron. This allows manganese and the radionuclides to be transported a long distance before they would be removed by precipitation and coprecipitation respectively. Because most of the "dissolved" iron in solutions at pH7 should be colloidal, manganese precipitation causes coagulation of the iron and enmeshment of the iron hydroxide within the hydrous manganese oxide.

The main question of modelling concern is the time of transport from the weir to Gunnar Central, the time of transport through the Gunnar Central tailings, and the solid-solution reactions within Gunnar Central and downstream to Langley Bay. If the time of transport is sufficiently long from the weir to Gunnar Central, most of the manganese and hence radionuclides may be removed from solution before entering Gunnar Central. If the time is sufficiently short, transport of all the radionuclides would occur from the weir to Gunnar Central. Then the key question is whether surface flow from the weir enters the oxidized or reduced zone of the Gunnar Central groundwater system, and whether there is substantial removal in Gunnar Central. Depending upon the flow time through Gunnar Central (e.g. weeks to centuries), the solid-solution mechanisms at the downstream end of Gunnar Central may control export of radionuclides to Langley Bay, making export to Langley Bay independent of export from Gunnar Main.

One other question would need to be addressed to evaluate export to Langley Bay - Is most of the input of radionuclides into Langley Bay due to export from Gunnar Central, or to diffusion from the tailing pore water.

6.5 References

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TABLE 6.1.1: CALENDAR OF MAJOR FIELD TRIPS FOR SURFACE WATER STUDIES

Date	Description
18 October:	Project Commencement
October or November:	Snowfall
03-10 December 1984:	Preliminary field reconnaissance, install weir and instrument housing. Stream was flowing under snow.
16-20 Mar 1985:	Complete installation of weir, seal with bentonite benching. Stream was frozen.
30 April to 03 May:	Install ISCO bubbler flow meter and sequential water sample.
30 April:	Runoff began, mostly local ice and snow melt.
01 May:	Instrumentation complete.
06 May:	Estimated date of leakage.
29 May:	First inspection - local observer.
06 June:	Second inspection - local observer.
08 June:	Weir repair - local observer.
12 June:	o Complete weir repair; recalibrate flow meter. o Beaver dam below Frog Pond and above Weir first noted.
22-24 June:	o Change 1 m wide weir to 0.1 m. o Calibrate flow meter. o retrieve samples. o Install water level recorders on Langley Bay.
26-30 July:	o Retrieve water samples. o Calibrate flow meter. o Check water level recorders on Langley Bay.
04 August:	o Weir chart ceased to record daily flow rate. o 12 V power supply disconnected.
25-29 August:	Last field compaign to retrieve equipment.
27 August:	Water level instrumentation removed.
November:	Equipment, shipped via barge, arrived in Toronto.

TABLE 6.1.2: MEASURED AND ESTIMATED DAILY FLOW RATES CUMULATIVE RUNOFF AND PRECIPITATION AT THE GUNNAR WEIR

Date	Daily Average Flow Rate (m^3/s)	Cumulative Flow (m^3)	Precipitation (mm)	Comments
May 01	0.025	2,123		
02	0.036	5,234	2.6	
03	0.080	12,153		
04	0.080	19,137	0.7	
05	0.039	22,485		
06*	0.027	24,818		Weir leak
07*	0.020	26,546		
08*	0.014	27,756	0.5	
09*	0.010	28,620		
10*	0.0086	29,363		
11*	0.0076	30,020		
12*	0.0069	30,616		
13*	0.0061	31,143		
14*	0.0054	31,610		
15*	0.0048	32,025		
16*	0.0043	32,397		
17*	0.0038	32,725		
18*	0.0034	33,019		
19*	0.0031	33,287		
20*	0.0027	33,520		
21*	0.0024	33,727		
22*	0.0021	33,908		
23*	0.0019	34,072		
24*	0.0017	34,219	1.3	
25*	0.0015	34,349	0.3	
26*	0.0014	34,470		
27*	0.0012	34,574		

TABLE 6.1.2: MEASURED AND ESTIMATED DAILY FLOW RATES CUMULATIVE RUNOFF AND PRECIPITATION AT THE GUNNAR WEIR

Date	Daily Average Flow Rate (m^3/s)	Cumulative Flow (m^3)	Precipitation (mm)	Comments
May 28*	0.0011	34,669		
29*	0.0010	34,755		
30*	0.00087	34,830		
31*	0.0078	34,897		
June 01*	0.00068	34,956		
02*	0.00061	35,009		
03*	0.00054	35,056		
04*	0.00052	35,101		
05*	0.0050	35,144		
06*	0.00038	35,177		
07*	0.00037	35,209	1.7	
08*	0.00036	35,240	1.6	
09*	0.00035	35,270		
10*	0.00035	35,300	0.2	
11*	0.00034	35,329		
12	0.00030	35,355		Weir repaired
13	0.0040	35,701		
14	0.0040	36,047	0.3	
15	0.0050	36,839		
16	0.0050	37,271	14.5	
17	0.0220	39,172	20.0	
18	0.0100	40,036		
19	0.0090	40,814		
20	0.0070	41,419		
21	0.0070	42,024	2.6	
22	0.0054	42,488		Weir width reduced
23	0.0018	42,642		

TABLE 6.1.2: MEASURED AND ESTIMATED DAILY FLOW RATES CUMULATIVE RUNOFF AND PRECIPITATION AT THE GUNNAR WEIR

Date	Daily Average Flow Rate (m^3/s)	Cumulative Flow (m^3)	Precipitation (mm)	Comments
June 24	0.0011	42,734		
25	0.009	42,812		
26	0.0008	42,881		
27	0.0007	42,942		
28	0.00065	42,998		
29	0.00060	43,050		
30	0.00055	42,097		
July 01	0.00050	43,140		
02	0.00055	43,188		
03	0.00055	43,236	1.7	
04	0.00050	43,279		
05	0.00045	43,318		
06	0.00045	43,357		
07	0.00045	43,396		
08	0.00045	43,435	0.5	
09	0.00045	43,473		
10	0.00040	43,608		
11	0.00045	43,546		
12	0.00045	43,585	3.9	
13	0.00045	43,624		
14	0.00045	43,663		
15	0.00045	43,702	8.8	
16	0.00045	43,741		
17	0.00037	43,773		
18	0.00035	43,803	1.6	
19	0.00040	43,838		
20	0.00045	43,877		

TABLE 6.1.2: MEASURED AND ESTIMATED DAILY FLOW RATES CUMULATIVE RUNOFF AND PRECIPITATION AT THE GUNNAR WEIR

Date		Daily Average Flow Rate (m^3/s)	Cumulative Flow (m^3)	Precipitation (mm)	Comments
July	21	0.00050	43,920	0.2	
	22	0.00070	43,980	9.4	
	23	0.00060	44,032	9.2	
	24	0.00040	44,075		
	25	0.00045	44,114		
	26	0.00040	44,149	5.0	
	27	0.00037	44,181	0.3	
	28	0.00030	44,207		
	29	0.00035	44,237	2.0	
	30	0.00030	44,263		
	31	0.00040	44,298		
Aug.	01	0.00040	44,333		
	02	0.00045	44,372		
	03	0.00050	44,415		
	04	0.00060	44,467		Power failure
	05*	0.00067	44,525	15.0	
	06*	0.00059	44,576	4.1	
	07*	0.00052	44,621	0.2	
	08*	0.00051	44,665		
	09*	0.00050	44,708		
	10*	0.00050	44,751		
	11*	0.00049	44,793		
	12*	0.00047	44,834	1.3	
	13*	0.00047	44,875	1.5	
	14*	0.00046	44,915		
	15*	0.00045	44,954		
	16*	0.00044	44,992		

TABLE 6.1.2: MEASURED AND ESTIMATED DAILY FLOW RATES CUMULATIVE RUNOFF AND PRECIPITATION AT THE GUNNAR WEIR

Date	Daily Average Flow Rate (m^3/s)	Cumulative Flow (m^3)	Precipitation (mm)	Comments
Aug. 17*	0.00043	44,929		
18*	0.00042	44,965		
19*	0.00042	45,001		
20*	0.00041	45,036	4.1	
21*	0.00040	45,071	2.1	
22*	0.00039	45,015		
23*	0.00038	45,138		
24*	0.00038	45,171		
25*	0.00037	45,203	17.3	
26*	0.00035	45,234	3.3	
27*	0.00035	45,264		
28*	0.00035	45,294		
29*	0.00034	45,223		
30*	0.00034	45,352	3.6	
31*	0.00033	45,381	0.2	

* Flow rate estimated using a runoff regression coefficient.

TABLE 6.2.1: SNOW CORE DATA

Grid Reference No.	Core Depth (m)	Water Equivalent (cm)
0 + 925	0.66	16.4
+ 900	0.57	18.4
+ 875	0.71	23.7
+ 850	0.85	24.8
+ 825	0.50	13.8
+ 800	0.64	19.7
+ 775	0.56	18.4
+ 750	0.28	5.3
+ 725	0.61	21.4
+ 700	0.55	15.1
+ 675	0.61	21.4
+ 650	0.74	22.4
+ 625	0.43	13.2
+ 600	0.20	4.6
+ 575	0.53	17.6
+ 550	0.38	10.3
+ 525	0.31	8.9
+ 500	0.31	8.9*
+ 475	0.24	6.9*
+ 450	0.31	8.9*
+ 425	0.28	8.0*
+ 400	0.18	5.2*
+ 375	0.47	11.8
+ 350	0.90	22.5
+ 325	1.18	41.4
+ 300	1.27	27.0
+ 275	0.81	18.4
+ 250	0.34	9.5
+ 225	0.38	10.7
+ 200	0.25	7.4
+ 175	0.25	7.7
+ 150	0.43	10.7
+ 125	0.36	8.3
+ 100	0.36	8.6
+ 075	0.51	14.8
+ 050	0.53	14.1
+ 025	0.38	10.5
AVERAGE	0.51	14.3

* Ice below this depth.

TABLE 6.2.1: SNOW CORE DATA

Grid Reference No.	Core Depth (m)	Water Equivalent (cm)
775E	1.01	30.3
750E	0.61	16.8
725E	0.31	7.2
700E	0.51	17.4
675E	0.38	10.8
650E	0.37	11.2
625E	0.43	11.2
600E	0.42	13.6
525E	0.36	10.2
550E	0.41	10.9
525E	0.28	8.1
500E	0.50	12.3
475E	0.36	10.1
450E	0.39	10.6
425E	0.57	19.1
400E	0.51	15.5
375E	0.51	15.8
350E	0.29	8.9
325E	0.23	6.1
300E	0.05	-
275E	0.58	10.3
250E	0.22	6.8
225E	0.43	14.8
200E	0.31	8.6
175E	0.22	6.4
150E	0.76	7.6
AVERAGE	0.44	12.9

TABLE 6.2.1: SNOW CORE DATA

Grid Reference No.	Core Depth (m)	Water Equivalent (cm)
25C	0.57	14.3
50C	0.44	13.7
75C	0.43	11.0
100C	0.43	11.6
125C	0.24	4.7
150C	0.47	14.7
175C	0.48	12.5
200C	0.34	9.9
AVERAGE	0.43	11.6
25N	0.60	19.7
50N	0.19	6.4
75N	0.57	12.3
100N	0.61	13.8
125N	0.55	13.5
150N	0.39	8.6
175N	0.51	12.5
AVERAGE	0.49	12.4

TABLE 6.3.1: MAJOR HYDROLOGICAL PATHWAYS IN LANGLEY BAY

Flow Pathway	Method of Evaluation
Cutoff Langley Bay - Drainage	Calculation
Cutoff Langley Bay - Rainfall	Measurement
Cutoff Langley Bay - Evaporation	Calculation
Langley Bay - Drainage	Calculation
Langley Bay - Rainfall	Measurement
Langley Bay - Evaporation	Calculation
Discharge from Gunnar Central	Calculation
Flow from Cutoff Langley Bay to Langley Bay	Water level recorder/Calculation
Exchange Flow Between Langley Bay and Lake Athabasca	Water Level Recorder/Calculation

TABLE 6.3.2a: EXAMPLE OF CONDUCTIVITY AND TDS DATA AVAILABLE

Parameter	Report	Weir	Cutoff Langley	Langley Bay	Lake Athabasca
Conductivity	BEAK 1984 data	9,000	780	160	-
	SRC Laboratory	-	430	120 (110-155)	110 (60-135)
	SRC Report	-	400	115 (110-130)	69 (68-70)
TDS	BEAK (Dec.) 1984 data	9,200	530	107	-

TABLE 6.3.2b: ESTIMATE OF EXCHANGE FLOWS USING DIFFERENT CONSERVATIVE SUBSTANCE

Parameter Used in Estimate	Value of B	Value of E*
Conductivity	200 (130-220)	4 (2.6-4.4) x 10^6 m^3/yr
Ca	80-850	(2-20) x 10^6 m^3/yr
Na	600	12 x 10^6 m^3/yr
Mg	450	9 x 10^6 m^3/yr
Sulphate	200-300	(4-6) x 10^6 m^3/yr
Potassium	50**-100	(1-2) x 10^6 m^3/yr

* Based upon Q_3 = 2 x 10^4 m^3/yr.

** Inferred value; see text.

TABLE 6.3.3: MORPHOMETRIC DATA FOR SURFACE WATERS*

	Water Body	
	Cutoff Langley Bay	Langley Bay
Surface Area (A, m^2)	170,000	717,000
Volume (V, m^3)	309,000	3,070,000
Mean Depth (Z, m)	1.82	4.09

* Relative to a Lake Athabasca datum of 24 June 1985.

TABLE 6.4.1a: GUNNAR SURFACE WATER - WEIR (December to April)

Parameter	Dec 84-1	Dec 84-2	March	Apr 30	May 2
pH	7.2	7.0	7.4	6.8	6.5
Conductivity (umhos/cm)	9,000	8,700	2,500	1,350/1,400	1,250/1,300
Acidity ($CaCO_3$, mg/L)	12	19			
Alkalinity ($CaCO_3$, mg/L)	87	78		14	12
Total Dissolved Solids (mg/L)	9,300	9,300/9,100		1,150	1,100
Volatile Dissolved Solids (mg/L)				150	170
TIC (mg/L)				2.0	1.5
TOC (mg/L)				14	25/24
Total Kjeldahl N (mg/L)	0.43	0.48/0.56		0.59	0.82/0.86
Ammonia-N	0.10	0.05		0.08	0.10
Nitrite-N (mg/L)	0.003	0.003/0.004			
Nitrate-N (mg/L)	0.15/0.15	0.15/0.15		0.7/0.5	0.7/0.5
Total Phosphate (mg/L)	0.01	0.01		0.15	0.22/0.21
IC Scan (mg/L):					
Fluoride	0.8	0.5	0.2	0.2	0.2
Chloride	540/540	380/390	97	46	39
Nitrite	L 10	L 10	L 2	L 0.1	L 0.4
O-Phosphate	L 2	L 2	L 0.1	L 0.2	L 1
Nitrate	L 1	L 1	L 0.2	L 0.4	L 0.4
Sulphate	5,100	3,300/3,500	1,230	820	700
DCP Scan (mg/L):					
Beryllium	L 0.005	L 0.005	L 0.01	L 0.01	L 0.01/L 0.01
Molybdenum	0.05	0.05	0.03	0.03	0.02/0.03
Calcium	450	400	210	147	128/129
Vanadium	0.02	0.02	0.01	0.010	0.010/0.010
Aluminum	0.48	0.48	0.22	0.64	0.93/0.93
Magnesium	1,230	1,210	230	107	104/104
Barium	0.04	0.04	0.02	0.030	0.030/0.030
Potassium	11.4	12.1	1.86	1.97	2.7/2.7
Strontium	1.73	1.59	0.70	0.38	0.34/0.34
Sodium	400	410	68	31	30/30
Zinc	0.070	0.085	0.050	0.025/0.020	0.025
Cadmium	L 0.01	0.01	0.005	0.005/L 0.005	0.010
Manganese	8.5	8.2	0.70	2.04/2.1	2.3
Cobalt	L 0.005	0.12	0.03	0.02/0.01	0.02
Copper	0.01	0.025	0.010	0.010/0.010	0.010
Silver				0.02/L 0.01	0.02
Iron	0.69	0.73	0.15	1.06/1.12	1.58
Lead	L 0.02	0.56	0.13	0.08/0.06	0.08
Chromium	L 0.01	0.04	0.02	0.01/L 0.01	0.01
Nickel	L 0.01	0.08	0.01	0.01/L 0.01	0.01
Silica (SiO_2)	17.5/17.0	17.5	6.2	6.7/6.6	10.0/10.0
Titanium	0.27	0.25/0.25	0.16	0.12/0.12	0.12
Boron			0.31/0.30	0.18/0.17	0.18/0.18
A.A. (ug/L):					
Selenium	L 0.5	L 0.5		L 0.5	L 0.5
Arsenic	6.5	4.0		1.5	1.5/1.0
Sum Anions	138.0	142.6		18.63	15.90
Sum Cations	141.5	138.0		17.53	16.34
% Difference				3.0	1.4
Radionuclides:					
Total U (ug/L)	4,250	4,050			
Th-230 (Bq/L)	1.97(±0.04)	2.09(±0.40)			
Ra-226 (Bq/L)	1.25(±0.23)	0.86(±0.27)			
Pb-210 (Bq/L)	1.4(±0.13)	1.4(±0.13)			
Po-210 (Bq/L)	1.82±0.15	2.66±0.39			

TABLE 6.4.1b: GUNNAR SURFACE WATER - WEIR (MAY TO JUNE)

Parameter	May W1	May W2	May-30 Run 1	May-30 Run 2	06 June	07 June	08 June	12/13 June	22 June	22 June
pH			7.2	7.7	7.4	7.6		7.5	7.7	
Conductivity (umhos/cm)			1,090	1,210	1,900	1,950		2,000	2,300	
Acidity ($CaCO_3$, mg/L)										
Alkalinity ($CaCO_3$, mg/L)					27	25		35	49	
Total Dissolved Solids (mg/L)					1,870	1,880		1,950	2,300	
Volatile Dissolved Solids (mg/L)										
TIC (mg/L)										
TOC (mg/L)					27			29	34	
Total Kjeldahl N (mg/L)					1.17			1.15	1.48	
Ammonia-N										
Nitrite-N (mg/L)										
Nitrate-N (mg/L)					0.06/0.09			0.03/0.03	0.07/0.16	
Total Phosphate (mg/L)										
IC Scan:										
Fluoride			0.1	0.1	0.4	0.4		0.3	0.4	
Chloride			28	35	60	74		70	84	
Nitrite			L 1	L 1	L 2	L 5		L 0.5	L 1	
O-Phosphate			L 1	L 1	L 0.1	L 5		L 0.5	L 1	
Nitrate			L 0.1	L 0.1	L 0.2	L 0.5		L 0.2	L 0.2	
Sulphate			560	650	1,090	1,040		1,140	1,400	
DCP Scan:										
Beryllium	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01		L 0.01	L 0.01	L 0.01	L 0.01
Molybdenum	0.02	0.01	0.01	0.01	0.03		0.02	0.03	0.02	0.03
Calcium	121	105	94	108	194		188	200	220	220
Vanadium	L 0.01	L 0.01	L 0.01	L 0.01	0.01		0.01	0.01	0.01	0.01
Aluminum	0.38	0.71	0.56	0.40	0.32		0.33	0.24	0.25	0.57
Magnesium	102	98	72	92	180		172	183	210	200
Barium	0.02	0.02	L 0.01	L 0.01	0.02		0.09	0.02	0.03	0.04
Potassium	1.71	2.4	1.99	1.95	3.9		3.8	4.2	4.9	4.7
Strontium	0.32	0.28	0.24	0.27	0.48		0.46	0.49	0.52	0.51
Sodium	29	28	21	27	49		47	51	61	56
Zinc	0.015	0.010	0.025/0.030	0.010	0.020		0.030	0.020	0.025/0.030	0.045
Cadmium	L 0.005	0.005	0.010/L 0.005	0.010	0.010		0.005	L 0.005	L 0.005/0.005	0.005
Manganese	1.80	1.99	0.39/0.38	0.59	3.3		5.7	6.1	9.1/9.1	5.8
Cobalt	0.02	0.02	0.01/0.01	0.01	0.02		0.03	0.02	0.03/0.02	0.03
Copper	0.010	0.005	0.030/0.035	0.015	0.010		0.010	0.010	0.010/0.010	0.035
Silver										
Iron	0.88	1.07	1.01/1.01	0.82	0.60		0.84	0.72	1.40/1.40	2.0

TABLE 6.4.1b: GUNNAR SURFACE WATER - WEIR (MAY TO JUNE)

Parameter	May W1	May W2	May-30 Run 1	May-30 Run 2	06 June	07 June	08 June	12/13 June	22 June	22 June
Lead	0.08	0.10	0.08/0.07	0.07	0.10		0.10	0.09	0.10/0.11	0.12
Chromium	0.01	0.01	0.01/0.01	0.01	0.02		0.02	0.02	0.02/0.01	0.02
Nickel	L 0.01	0.01	L 0.01/0.01	L 0.01	0.02		0.01	0.01	0.02/0.02	0.02
Silica (SiO_2)	6.3	9.6	8.0/8.0	6.9/7.4	13.9		14.5/14.1	14.1	22	20
Titanium	0.11	0.10	0.10/0.10	0.10	0.15		0.14	0.17	0.16	0.18/0.20
Uranium										
Boron	0.24	0.15	0.18	0.16	0.36/0.28		0.28	0.30	0.31	0.30
Selenium										
Arsenic					L 1		L 1	L 1	1/2	
Sum Anions					24.3	-	-	26.4	32.5	
Sum Cations					26.7	-	-	27.4	31	
% Difference					3.5	-	-	1.9	2.4	
Radionuclides:										
Total U (ug/L)	265	-	220	-	210	210	255	260	415	
Th-230 (Bq/L)	1.4	-	2.1	-	0.42	0.40	-	0.50	0.66	
Ra-226 (Bq/L)	1.85	-	4.1	-	0.52	0.73	0.65	0.71	1.95	
Pb-210 (Bq/L)	6.0	-	-	-	0.75	-	-	L 0.7	L 0.7	

TABLE 6.4.1c: GUNNAR SURFACE WATER - WEIR (JULY/AUGUST)

Parameter	July Comp 1	July Comp 3	July Comp 5	August* Bottle 1	August* Bottle 5	August* Bottle 10
pH	7.5	7.5	7.5	7.6	7.6	7.5
Conductivity (umhos/cm)	2,600	2,900	3,200	3,400	3,400	3,400
Alkalinity ($CaCO_3$, mg/L)	47	63	65	68	80	83/81
DOC (mg/L)				30	31	31
Total Kjeldahl N (mg/L)				1.20	1.10	1.22/1.11
IC Scan:						
Fluoride	0.6/0.5	0.5	0.1			
Chloride	130/130	148	168			
Nitrite	L 2	L 2	L 2			
O-Phosphate	L 2	L 2	L 2			
Bromide	0.2/0.3	0.3	0.3			
Nitrate	L 0.2	L 0.2	L 0.2			
Sulphate	1,900	2,100	2,300			
DCP Scan:						
Beryllium	L 0.005	L 0.005	L 0.005	L 0.005	0.005	0.005
Molybdenum	0.08	0.08	0.08	1.0	0.10	0.10
Calcium	250	290	320	350/320	360/310	350/300
Vanadium	0.025	0.010	0.020	0.025	0.030	0.025
Aluminum	0.51	0.49	0.53	0.55	0.55	0.58
Magnesium	310	340	380	410	420	410
Barium	0.045	0.045	0.050	0.060	0.055	0.055
Potassium	5.3	6.3	7.0	7.8	8.1	8.5
Strontium	0.62	0.72	0.76	0.88	0.88	0.85
Sodium	92	106	115	132/122	132/122	129/122
Zinc	0.040	0.050	0.060	0.050	0.060	0.045
Cadmium	0.010	0.010	0.010	0.010	0.010	0.005
Manganese	13.1	22	23	24	28	24
Cobalt	0.040	0.065	0.065	0.075	0.075	0.050
Copper	0.010	0.020	0.020	0.015	0.020	0.015
Silver	0.02	0.04	0.02	0.02	0.02	0.01
Iron	0.90	0.93	1.25	0.52	1.05	1.86
Lead	0.14	0.21	0.14	0.22	0.23	0.13
Chromium	0.015	0.030	0.010	0.030	0.025	0.005
Nickel	0.020	0.030	0.025	0.040	0.045	0.020
Silica (SiO_2)	15.3/16.7	14.1	12.5	13.1	11.3	10.6
Titanium	0.15	0.16	0.17/0.17	0.22	0.22	0.23
Radionuclides:						
Total U (ug/L)	525	1,250	1,400	1,450	2,100	1,650
Th-230 (Bq/L)	0.42	0.29	0.28	0.25	-	0.19
Ra-226 (Bq/L)	1.73	1.63	2.17	1.93	1.53	1.7
Pb-210 (Bq/L)	L 0.7	L 0.7	L 0.7	1.6	-	L 1.0

* For radionuclides, Bottles 3, 6 and 9 respectively were used.

TABLE 6.4.2: GUNNAR SURFACE WATER - CUTOFF LANGLEY BAY

Parameter	Dec 84	Mar 85-1	Mar 85-2	Mar 85-3	24 June	27 July	28 Aug**
pH	7.7	7.2	7.2	7.1	7.9		
Conductivity (umhos/cm)	780	940	940	940	560		
Acidity ($CaCO_3$, mg/L)	6						
Alkalinity ($CaCO_3$, mg/L)	45	105	108	105	54		
Total Dissolved Solids (mg/L)	530	710	710	720	430		
Volatile Dissolved Solids (mg/L)		550	550	560			
TIC (mg/L)		26	28	28			
TOC (mg/L)		10.5	15	12	14.0		
Total Kjeldahl N (mg/L)	0.29	0.95	0.99	1.30	0.50/0.51		
Ammonia-N	0.04	0.03	0.04	0.11			
Nitrite-N (mg/L)	L 0.003						
Nitrate-N (mg/L)	0.15/0.10	0.9/0.6	0.8/0.5	0.8/0.5	0.06/0.03		
Total Phosphate (mg/L)	L 0.01	0.45	0.30/0.40	0.50			
IC Scan (mg/L):							
Fluoride	0.23/0.21	0.2	0.2	0.2	0.15		
Chloride	18.1/18.1	25	26	26	13.0		
Nitrite	L 0.5	L 0.5	L 0.5	L 0.2	L 0.5		
O-Phosphate	L 0.2	L 0.2	L 0.2	L 0.2	L 0.5		
Nitrate	L 0.2	L 0.5	L 0.5	L 0.5	L 0.05		
Sulphate	263	420	480	460	250		
DCP Scan (mg/L):							
Beryllium	L 0.005	L 0.01/L 0.01	L 0.01	L 0.01	L 0.01	L 0.005	L 0.0005
Molybdenum	0.005	0.02/0.02	0.02	0.02	L 0.01	0.02	L 0.2
Calcium	48	109/103	111	108	52	56	62
Vanadium	L 0.005	0.01/0.01	L 0.01	L 0.01	L 0.01	L 0.005	L 0.005
Aluminum	0.06	0.14/0.13	0.14	0.14	0.06	0.10	L 0.01
Magnesium	36	57/55	57	57	33	36	37
Barium	0.02	0.06/0.05	0.06	0.06	0.02	L 0.005	0.016
Potassium	2.4	4.8/4.5	4.7	4.7	2.4	2.1	3.0
Strontium	0.15	0.30/0.28	0.30	0.29	0.14	0.16	0.16
Sodium	11.4	19.9/19.0	19.7	19.3	10.5	9.1	13
Zinc	0.005	0.01/0.03	0.02	0.01	L 0.005	L 0.005	L 0.05
Cadmium	L 0.01	L 0.01/L 0.01	0.01	0.005	L 0.005	L 0.005	L 0.01
Manganese	0.03	2.9/2.8	2.9	2.9	0.08	0.010	L 0.01
Cobalt	L 0.01	0.01/0.01	0.01	0.01	L 0.01	0.005	0.05
Copper	0.01	L 0.01/0.01	L 0.01	0.01	L 0.005	L 0.005	L 0.008
Silver		L 0.005/L 0.005	L 0.005	L 0.01	-	L 0.01	0.009
Iron	L 0.01	3.5/3.3	3.4	3.6	0.16	0.12	0.05
Lead	0.04	0.04/0.04	0.04	0.03	0.02	0.02	L 0.05

TABLE 6.4.2: GUNNAR SURFACE WATER - CUTOFF LANGLEY BAY

Parameter	Dec 84	Mar 85-1	Mar 85-2	Mar 85-3	24 June	27 July	28 Aug**
Chromium	L 0.01	0.01/0.01	0.01	0.01	0.01	L 0.005	0.07
Nickel	0.01	0.01/L 0.01	0.01	L 0.01	L 0.01	0.010	L 0.05
Silica (SiO_2)	1.1/1.2	5.4/5.5	5.6/5.6	5.4/5.2	5.0	2.9	0.94
Titanium	0.05	0.07	0.07/0.0	0.07	0.05	0.004	L 0.005
Boron		0.12	0.12	0.12	0.08	0.08	0.023
A.A. (ug/L):							
Selenium	L 0.5	L 0.5	L 0.5	L 0.5			
Arsenic	L 0.5	12	9.5	10			
Sum Anions	6.88	11.54	12.88	12.40	6.65		
Sum Cations	6.03	11.13	11.49	11.33	5.80		
% Difference		1.8	5.7	4.5	6.0		
Radionuclides:							
Total U (ug/L)	10	21/19(±2)	21/21(±4)	24/20(±2)	16		14
Th-230 (Bq/L)	+	0.101(±0.014)/0.12	0.156(±0.019)/0.13	0.130(±0.017)/L 0.2	0.10		
Ra-226 (Bq/L)	L 2	1.91(±0.11)/2.0	2.04(±0.01)/1.8	2.16(±0.13)/L 2.0	0.45	0.20 (± 0.01)	0.40 (± 0.02)
Pb-210 (Bq/L)	+	0.32(±0.04)	3.85±0.32	2.60±0.24	-		
Po-210 (Bq/L)	+	0.38(±0.17)*	0.49(±0.14)*	1.47(±0.15)*			

* 9 May 1985 for data sampled March 1985.

** ICP results; remainder are DCP.

+ Insufficient sample for adequate analysis.

TABLE 6.4.3: GUNNAR SURFACE WATER - LANGLEY BAY

Parameter	Dec 84	Mar 85-1	Mar 85-2	Mar 85-3	24 June	Jul 85-27	Aug 85-28**
pH	7.5	7.1	7.5	7.2	7.8		
Conductivity (umhos/cm)	160	161	161	161	105		
Acidity ($CaCO_3$, mg/L)	6						
Alkalinity ($CaCO_3$, mg/L)	37/31	38	37	38/38	27		
Total Dissolved Solids (mg/L)	107	105	104	105/96	64		
Volatile Dissolved Solids (mg/L)		77	69	64/66			
TIC (mg/L)		8.0	8.0	8.5			
TOC (mg/L)		6.0	5.0	5.5	2.0		
Total Kjeldahl N (mg/L)	0.06	0.44	0.65	0.32/0.40	0.30		
Ammonia-N	0.04/0.05	0.05	0.18	0.09/0.09			
Nitrite-N (mg/L)	L 0.003						
Nitrate-N (mg/L)	0.05/0.05	0.9/0.6	0.8/0.5	0.8/0.5	0.05/0.05		
Total Phosphate (mg/L)	0.01	0.30	0.30	0.50/0.40			
IC Scan (mg/L):							
Fluoride	0.09	0.1	0.1	0.2	0.07		
Chloride	5.3	5.2	5.2	6.1	3.4		
Nitrite	L 0.5	L 0.05	L 0.05	17	L 0.1		
O-Phosphate	L 0.2	L 0.2	L 0.2	L 2	L 0.1		
Nitrate	L 0.2	L 0.2	L 0.2	L 1	0.02		
Sulphate	21	24	24	25	14.5/16.5		
DCP Scan (mg/L):							
Beryllium	L 0.005	L 0.01	L 0.01	L 0.01	L 0.01	L 0.005	L 0.0005
Molybdenum	0.010	L 0.01	L 0.01	L 0.01	L 0.01	0.01	L 0.2
Calcium	7.7/9.3	15.6	15.2	15.2	9.2	12.2	13.1
Vanadium	L 0.005	L 0.01	L 0.01	L 0.01	L 0.01	L 0.005	0.012
Aluminum	0.02	0.04	0.04	0.03	0.06	0.06	0.03
Magnesium	4.6/4.6	6.7	6.8	6.4	3.7	5.1	4.78
Barium	0.02	0.02	0.02	0.02	0.01	0.015	0.017
Potassium	0.79	1.46	1.44	1.32	0.92	1.14	2.0
Strontium	0.05	0.09	0.09	0.09	0.06	0.07	0.067
Sodium	2.7	4.5	4.7	4.6	2.7	3.6	4.0
Zinc	L 0.005	0.01	0.005	L 0.005	L 0.005	L 0.005	L 0.05
Cadmium	L 0.01	L 0.005	0.005	0.005	L 0.005	L 0.005	L 0.01
Manganese	L 0.01	0.01	0.01	L 0.01	L 0.01	0.005	L 0.01
Cobalt	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01	L 0.005	0.05
Copper	L 0.005	0.005	0.01	0.01	L 0.005	0.005	L 0.08
Silver		L 0.01	L 0.01	L 0.01	-	L 0.01	0.006
Iron	L 0.01	0.05	0.04	0.03	0.05	0.06	L 0.01
Lead	L 0.02	0.01	0.02	L 0.01	L 0.01	0.01	L 0.05

TABLE 6.4.3: GUNNAR SURFACE WATER - LANGLEY BAY

Parameter	Dec 84	Mar 85-1	Mar 85-2	Mar 85-3	24 June	Jul 85-27	Aug 85-28**
Chromium	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01	0.010	0.02
Nickel	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01	L 0.005	L 0.05
Silica (SiO_2)	3.1	3.8/3.6	3.8/3.7	3.6/3.6	3.7	2.7	1.8
Titanium	0.02	0.02	0.02	0.02	0.02	0.03	L 0.005
Boron		0.02	0.05	0.03	L 0.01	0.02	L 0.004
A.A. (ug/L):							
Selenium	L 0.5	L 0.5	L 0.5	L 0.5			
Arsenic	0.5	0.5	0.5/1.0	0.5			
Sum Anions	1.27	1.41	1.39	1.45	0.96		
Sum Cations	1.02	1.56	1.56	1.52	0.98		
% Difference		5.0	5.8	3.6	3.2		
Radionuclides:							
Total U (ug/L)	-	4	9	3	5		0.5
Th-230 (Bq/L)	-	0.023(±0.002)	0.017(±0.002)	0.012(±0.005)	L 0.05		-
Ra-226 (Bq/L)	0.51(±0.23)	0.18(±0.03)	0.20(±0.04)	0.20(±0.03)	0.19	0.18 (± 0.01)	0.21 (± 0.4)
Pb-210 (Bq/L)	-	1.0(±0.1)+	2.68(±0.23)+	0.54(±0.06)	-		
Po-210 (Bq/L)	0.62±0.14	0.29(±0.09)*	0.17(±0.08)*	0.31(±0.11)*			

* 9 May 1985 for data sampled March 1985.

** ICP results; remainder are DCP.

+ Values are suspected as being too high.

TABLE 6.4.4: GUNNAR SURFACE WATER - LAKE ATHABASKA

Parameter	March 85-1	March 85-2	March 85-3	July 85-25
pH	7.4	7.2	7.1	
Conductivity (umhos/cm)	89	98/90	95/93	
Alkalinity ($CaCO_3$, mg/L)	30/30	31	29	
Total Dissolved Solids (mg/L)	59	68	65	
Volatile Dissolved Solids (mg/L)	34	37	37	
TIC (mg/L)	5.5	5.5	6.0	
TOC (mg/L)	5.0	6.5	3.0	
Total Kjeldahl N (mg/L)	0.74	0.92	0.73	
Ammonia-N	0.04	0.05	0.04	
Nitrate-N (mg/L)	0.7/0.5	0.8/0.5	0.8/0.5	
Total Phosphate (mg/L)	0.75	0.35	0.45	
IC Scan (mg/L):				
Fluoride	0.1	0.1	0.1	
Chloride	3.7	4.3	4.0	
Nitrite	L 0.5	L 0.5	L 0.5	
O-Phosphate	L 0.2	L 0.2	L 0.2	
Nitrate	L 0.2	0.2	L 0.2	
Sulphate	5.5	6.2	4.7	
DCP Scan (mg/L):				
Beryllium	L 0.01	L 0.01	L 0.01	L 0.005
Molybdenum	L 0.01	L 0.01	L 0.01	L 0.01
Calcium	9.7	9.8	10.0	7.4
Vanadium	L 0.01	L 0.01	L 0.01	L 0.005
Aluminum	0.06	0.03	0.02	0.05
Magnesium	2.9	3.0	3.0	2.5
Barium	0.01	0.01	0.01	0.01
Potassium	1.44	1.33	1.31	0.96
Strontium	0.07	0.07	0.08	0.06
Sodium	3.3	3.4	3.2	1.2
Zinc	0.02/0.01	0.01	0.01	0.005
Cadmium	L 0.01/L 0.01	L 0.01	L 0.01	0.005
Manganese	0.02/0.01	0.01	0.01	L 0.005
Cobalt	L 0.01/L 0.01	L 0.01	L 0.01	0.010
Copper	0.01/0.01	0.01	L 0.01	L 0.005
Silver	L 0.005/L 0.005	L 0.005	L 0.005	0.01
Iron	1.00/0.52	0.45	0.33	0.03
Lead	0.01/0.02	L 0.01	0.01	0.04
Chromium	L 0.01/L 0.01	L 0.01	L 0.01	0.005
Nickel	L 0.01/L 0.01	L 0.01	0.01	L 0.005
Silica (SiO_2)	3.6/3.7	3.6/3.7	3.6/3.8	3.1
Titanium	0.01/0.01	0.01	0.01	0.01
Boron	0.01	0.02	0.01	0.01
A.A. (ug/L):				
Selenium	L 0.5	L 0.5	L 0.5	
Arsenic	1.0	0.5	0.5/1.0	
Sum Anions	0.82	1.23	0.47	
Sum Cations	0.90	0.92	0.92	
% Difference	4.6	14.5	3.2	
Radionuclides:				
Total U (ug/L)	7	6	2	
Th-230 (Bq/L)	L 0.005	L 0.005	0.007(±0.004)	
Ra-226 (Bq/L)	L 0.005	L 0.005	L 0.005	L 0.01
Pb-210 (Bq/L)	L 0.1	*	*	
Po-210 (Bq/L)	*	*	*	
Th-232 (Bq/L)	L 0.005	L 0.005	L 0.005	
Th-228 (Bq/L)	L 0.005	L 0.005	L 0.005	

* Values are given by laboratory, but must be erroneous.

TABLE 6.4.5: GUNNAR SURFACE WATER - SNOW SAMPLES

Parameter	K1-20S	K2-30E	K2-10S
pH	6.7	6.7	7.3
Conductivity (umhos/cm)	218	40	90
Total Dissolved Solids (mg/L)	141	19	47/47
Total Suspended Solids (mg/L)	1.0	1.0	4/13
Total Kjeldahl N (mg/L)	0.25	0.24/0.31	0.25
IC Scan:			
Fluoride	0.08	0.03	0.04
Chloride	1.8	1.2	1.3
Nitrite	L 0.1	L 0.1	L 0.1
O-Phosphate	L 0.1	L 0.1	L 0.1
Nitrate	0.19	0.14	0.21
Sulphate	89	8.8	22
DCP Scan:			
Beryllium	L 0.005	L 0.005	L 0.005
Molybdenum	0.02	L 0.01	0.01
Calcium	35	3.5	18.6
Vanadium	0.005	L 0.005	L 0.005
Aluminum	0.10	0.08	0.24
Magnesium	0.79	0.31	0.69
Barium	0.050	0.020	0.115
Potassium	0.25	0.32	0.23
Strontium	0.05	L 0.01	0.03
Sodium	0.1	L 0.1	L 0.1
Zinc	7.0	2.4	2.9
Cadmium	L 0.005	L 0.005	L 0.005
Manganese	0.04	0.01	0.02
Cobalt	0.01	L 0.01	L 0.01
Copper	0.005	0.020	0.010
Silver	L 0.01	L 0.01	L 0.01
Iron	0.09	0.13	0.70
Lead	0.03	0.07	0.02
Chromium	0.010	L 0.005	0.005
Nickel	0.01	0.02	0.01
Silica (SiO_2)	1.85	0.60	1.60
Titanium (ug/L)	3	2	5

TABLE 6.4.6: GUNNAR SURFACE WATER - AIRPORT ROAD

Parameter	22 June	July
pH	6.9	7.6
Conductivity (umhos/cm $^{-1}$)	660	990
Alkalinity ($CaCO_3$, mg/L)	8	87
Total Dissolved Solids (mg/L)	610	840/850
TIC (mg/L)		21
TOC (mg/L)		24
Total Kjeldahl N (mg/L)		0.93
IC Scan:		
Fluoride	0.1	0.3
Chloride	11.0	13
Nitrite	L 0.5	L 0.2
O-Phosphate	L 0.5	L 0.2
Bromide		L 0.1
Nitrate	L 0.1	L 0.05
Sulphate	340	520
DCP Scan:		
Beryllium	L 0.01	L 0.01/L 0.01
Molybdenum	0.01	0.03/0.03
Calcium	89	155/154
Vanadium	L 0.01	0.01/0.01
Aluminum	0.25	0.18/0.17
Magnesium	27	59/59
Barium	0.02	0.04/0.04
Potassium	0.64	2.7/2.7
Strontium	0.19	0.34/0.34
Sodium	9.0	14.8/14.7
Zinc	L 0.005	0.015/0.010
Cadmium	L 0.005	L 0.005/L 0.005
Manganese	0.02	0.30/0.30
Cobalt	L 0.01	0.03/0.03
Copper	0.010	0.005/0.010
Silver	0.23	
Iron		0.38/0.40
Lead	0.02	0.07/0.09
Chromium	L 0.01	0.03/0.02
Nickel	L 0.01	0.02/0.01
Silica (SiO_2)	16.3	7.7
Titanium	0.08	
Boron	0.08	
Sum Anions	3.54	12.9
Sum Cations	3.1	13.2
% Difference	3.2	1.2
Radionuclides:		
Total U (ug/L)	18	
Ra-226 (Bq/L)	0.71	

TABLE 6.4.7: GUNNAR SURFACE WATER - CENTRAL MAIN

Parameter	22 June	July
pH	6.7	4.6
Conductivity (umhos/cm)	2,500	6,500
Acidity ($CaCO_3$, mg/L)		97
Alkalinity ($CaCO_3$, mg/L)	6	6
Total Dissolved Solids (mg/L)	2,300/2,400	7,800
TIC (mg/L)		2.5
TOC (mg/L)		16.5
Total Kjeldahl N (mg/L)		0.67
IC Scan:		
Fluoride	0.3	1.4
Chloride	80	240
Nitrite	L 0.1	L 1
O-Phosphate	L 1	L 1
Bromide		L 1
Nitrate	L 0.2	L 1
Sulphate	1,480	4,900
DCP Scan:		
Beryllium	L 0.01	0.01
Molybdenum	0.03	0.07
Calcium	210	490
Vanadium	0.01	0.03
Aluminum	0.28	5.7
Magnesium	220	910
Barium	0.01	0.04
Potassium	3.7	7.1
Strontium	0.48	2.0
Sodium	59	200
Zinc	0.035/0.030	0.21
Cadmium	0.010/0.005	0.015
Manganese	0.41/0.41	24
Cobalt	0.02/0.02	0.17
Copper	0.030/0.030	0.080
Iron	0.17/0.17	0.46
Lead	0.10/0.11	0.44
Chromium	0.02/0.02	0.05
Nickel	0.02/0.02	0.18
Silica (SiO_2)	17.5	40/40
Titanium	0.15	
Boron	0.38	
Sum Anions	33.2	108.8
Sum Cations	31.2	108.1
% Difference	3.1	0.3
Radionuclides:		
Total U (ug/L)	49.5	

TABLE 6.4.8: GUNNAR SURFACE WATER - ZEMEL CREEK

Parameter	22 June	July
pH	7.9	7.3
Conductivity (umhos/cm^{-1})	106	122
Alkalinity ($CaCO_3$, mg/L)	41/44	46
Total Dissolved Solids (mg/L)	49	44
TIC (mg/L)		15.0
TOC (mg/L)		3.5
Total Kjeldahl N (mg/L)		0.50/0.43
IC Scan:		
Fluoride	0.08	0.08/0.9
Chloride	1.5	1.6/1.6
Nitrite	0.1	0.1
O-Phosphate	L 0.1	L 0.1
Bromide		L 0.05
Nitrate	0.02	L 0.01
Sulphate	5.7	5.0/4.4
DCP Scan:		
Beryllium	L 0.01	L 0.01
Molybdenum	L 0.01	L 0.01
Calcium	11.8	13.7
Vanadium	L 0.01	L 0.01
Aluminum	0.12	0.03
Magnesium	4.9	5.5
Barium	0.02	0.02
Potassium	0.98	1.13
Strontium	0.04	0.05
Sodium	1.6	1.9
Zinc	L 0.005	L 0.005
Cadmium	L 0.005	L 0.005
Manganese	0.02	0.01
Cobalt	L 0.01	L 0.01
Copper	0.010	L 0.005
Iron	0.18	0.11
Lead	L 0.01	0.02
Chromium	L 0.01	L 0.01
Nickel	L 0.01	L 0.01
Silica (SiO_2)	2.6	1.59
Titanium	0.03	
Boron	0.02/0.02	
Nitrite N*		0.003
Sum Anions	1.01	1.07
Sum Cations	1.09	1.25
% Difference	3.8	7.8
Radionuclides:		
Total U (ug/L)	3.0	
Ra-226 (Bq/L)	L 0.01	

* Analyzed by wet method.

TABLE 6.4.9: GUNNAR SURFACE WATER - OTHER OCCASIONAL SPOTS SAMPLED

Parameter	Frog Pond 22 June	Gunnar Main West Outlet (July Comp.)	Southwest Gunnar Main (July Comp.)	Flooded Pit (July Comp.)	Waste Rock Seepage (July)*	Waste Rock Seepage (August)	Pit Runoff (25 Aug 85)
pH	7.2	6.2	7.9	8.8	8.30	6.1	8.0
Conductivity (umhos/cm^{-1})	2,500	700	5,900	290	-	580	285
Alkalinity ($CaCO_3$, mg/L)	43	240	126	60	116	39	61
Total Dissolved Solids (mg/L)	2,500	380	6,700	198	-	-	-
DOC (mg/L)	-	L 0.5	13.5	1.0	16	34	4.0
DIC (mg/L)	-	54	34	15.0	25	-	-
Total Kjeldahl N (mg/L)	-	0.22	0.52	0.46	-	-	-
IC Scan:							
Fluoride	0.4	0.09	1.0	0.14/0.13	0.78	0.4/0.4	0.14
Chloride	92	50	330	6.4/6.7	14	8.0/7.5	6.6
Nitrite	L 1	L 0.2	L 1	L 0.1	-	L 0.1	L 0.1
O-Phosphate	L 1	L 0.2	L 1	L 0.1	-	L 0.1	0.1
Bromide	-	L 0.1	L 1	0.05/0.05	0.20	-	-
Nitrate	L 0.2	1.1	L 1	L 0.05	-	0.5	L 0.01
Sulphate	1,500	50	4,200	75/76	930	270	74
DCP Scan:							
Beryllium	L 0.01/0.01	L 0.01	L 0.01	L 0.01	L 0.001	L 0.005	L 0.005
Molybdenum	0.03/0.02	0.02	0.07	0.01	0.006	0.07	0.02
Calcium	230/220	107	460	38	298	74	37
Vanadium	0.01/L 0.1	0.01	0.03	L 0.01	0.01	0.015	L 0.005
Aluminum	0.20/0.2	0.11	0.44	0.10	0.65	0.40	0.14
Magnesium	-/220	22	770	11.3	70	39	11.8
Barium	0.02/L 0.1	0.11	0.03	0.03	0.058	0.040	0.030
Potassium	5.0/4.0	1.3	7.6	2.5	2.3	5.3	2.6
Strontium	0.56/0.6	0.47	1.65	0.18	0.47	0.39	0.18
Sodium	70/68	19.9	240	6.1	43	14.3	6.5
Zinc	0.025	2.3	0.050	0.005	0.049	0.020	L 0.005
Cadmium	L 0.005	0.005	0.005	L 0.005	L 0.001	0.005	L 0.005
Manganese	3.8	0.01	0.25	L 0.01	0.25	0.43	0.015
Cobalt	0.02	0.02	0.09	0.01	0.002	0.22	0.005
Copper	0.005	0.015	0.03	L 0.005	0.031	0.015	0.005
Silver	-	-	-	-	-	0.02	0.01
Iron	0.98	0.09	0.83	0.03	0.34	0.26	0.05
Lead	0.05	0.13	0.38	0.05	L 0.005	0.33	0.02
Chromium	L 0.01	0.01	0.04	L 0.01	0.002	0.010	0.005
Nickel	L 0.01	0.01	0.04	L 0.01	0.008	0.025	0.005
Silica (SiO_2)	23	14.8	0.63	0.48/0.49	7.5	6.3	0.62
Titanium	0.16	-	-	-	0.003	0.11	0.04
Boron	0.40/0.37	-	-	-	-	-	-
Sum Anions	24.7	7.25	99.2	2.96	-	-	-
Sum Cations	23.8	8.05	96.9	3.15	-	-	-
% Difference	2	5.2	1.2	3.1	-	-	-
Radionuclides:							
Total U (ug/L)					8,400	15,000	500
Th-230 (Bq/L)					-	0.20±0.03	L 0.01
Ra-226 (Bq/L)					3.0	1.0	0.23
Pb-210 (Bq/L)					0.9		

* SRC analysis.

TABLE 6.4.10a: MAJOR ELEMENT ANALYSIS OF 06 JUNE PRECIPITATE

	Filtered Matter*			Filtrate**			
Parameter	Glass Fiber First Bottle	Glass Fiber Second Bottle[+,c]	0.45 micron Second Bottle[+,c]	First Bottle	Second Bottle	6 Jun**	8 Jun**
Al	a	0.3[b]	0.031	0.45	0.26	0.32	0.33
Ba	a	0.008	0.0008	0.03	0.02	0.02	0.09
Be	0.0001	L 0.0005	L 0.0005	L 0.0005	L 0.0005	L 0.01	L 0.01
Cr	0.0023/0.005	0.0026	L 0.0005	-	0.016	0.02	0.02
Cd	0.0016	0.0014	L 0.0005	-	0.005	0.01	0.005
Co	0.0044/0.004	0.0015	L 0.0005	-	0.02	0.02	0.03
Ca	(1.62/1.51)[b]	(1.8)[b]	0.1	210	183	194	188
Cu	0.004/0.004	0.0027	0.0006	-	.015	0.01	0.01
Fe	0.49/0.44	0.96	0.26	-	0.15	0.60	0.84
K	a	0.07	0.008	3.8	3.6	3.9	3.8
Mg	(0.38/0.33)[b]	(0.5)[b]	0.079	185	168	180	172
Mn	2.31	2.67	0.22	-	0.68	3.3	5.7
Mo	0.0018/0.003	L 0.0005	L 0.0005	0.07	0.05	0.03	0.02
Na	a	0.05	L 0.01	52	51	49	47
Ni	0.009/0.018	0.026	0.0056	-	0.025	0.02	0.01
Pb	0.012/0.02	0.007	L 0.001	-	0.12	0.10	0.10
Sr	0.035/0.032	0.004	L 0.0005	0.50	0.43	0.48	0.46
V	0.0014/0.001	0.0011	L 0.0005	0.015	0.005	0.01	0.01
Zn	a	0.013	L 0.0005	-	L 0.005	0.02	0.03
Anion Cation Balance (% Difference)						3.5%	

* Units mg/filter paper.

** Units mg/L

[+] Bottle No. 2 was filtered first with glass fiber filter and then with 0.45 micron filter.

[a] High blank background

[b] Values are real, but may not be too different from zero because they are the difference between two large numbers which are of the same order of magnitude. In particular the aluminum value would appear to be not real because it is of the same order of magnitude as the total concentration.

[c] Detection limits for the glass fiber and 0.45 micron filter papers are different because different dilutions were used in the analysis.

TABLE 6.4.10b: RADIONUCLIDE ANALYSIS OF 06 JUNE PRECIPITATE

Parameter	Whole Bottle Replicate 1	Whole Bottle Replicate 2	Precipitate on Filter Paper*	Blank Filter Paper
U (ug/L)	210	210	42.2	0.3
Ra-226 (Bq/L)	0.52	0.73	0.58	-
Th-230 (Bq/L)	0.42	0.40	0.33	-

* Three different 1 L bottles were filtered and each filter paper analyzed for a different radionuclide parameter. All bottles were from the 06 June sampling. Values for filter paper are re-expressed on a per litre of liquid basis.

TABLE 6.4.11: INTERLABORATORY COMPARISON OF RADIONUCLIDE ANALYSIS BY LABORATORIES FOR APRIL-MAY 1985 PERIOD

Date/Lab #	U (ppm)	Th-230 (Bq/L)	Ra-226 (Bq/L)	Th-232 (Bq/L)	Ra-228 (Bq/L)	Th-228 (Bq/L)
SW-C1 March (Cut-off Langley)						
SRC	0.019	0.12	2.0	L 0.1	0.11	L 0.1
Monenco	0.021	0.101	1.91	L 0.005	L 4.0	0.022
SW-C2 March (Cut-off Langley)						
SRC	0.021	0.13	1.8	L 0.1	0.35	L 0.1
Monenco	0.021	0.156	2.04	L 0.005	L 4.0	0.26
SW-C3 March (Cut-off Langley)						
SRC	0.020	L 0.2	2.0	L 0.2	0.4	L 0.2
Monenco	0.024	0.130	2.16	L 0.005	L 4.0	L 0.005
SW-01 March 25 (Lacnor)						
Chemex	0.210	4.1	2.1	0.9	0.60	1.0
SRC	0.125	5.5	1.7	0.45	0.80	0.45
Monenco	0.24	5.09	0.41	0.122	L 4.0	0.092
SW-01 March 29 (Lacnor)						
Chemex	0.240	4.2	1.6	1.2	0.4	1.2
SRC	0.200	7.5	1.2	0.50	0.55	0.50
Monenco	0.260	6.85	0.57	0.43	L 4.0	0.377
SW-02 March 25 (Lacnor)						
Chemex	0.090	3.9	1.8	1.2	0.5	1.0
SRC	0.115	4.0	1.1	0.60	0.30	0.60
Monenco	0.109	4.02	0.27	0.184	L 4.0	Th-227 present

TABLE 6.4.12: QUALITY ASSURANCE MONITORING OF RADIONUCLIDE PARAMETERS FOR JULY-AUGUST PERIOD FOR GUNNAR

a) Repeatability Measurements by Monenco

		Parameter	
Sample Label	U (ppb)	Ra-226 (Bq/L)	Th-230 (Bq/L)
W-06 June*	210	0.52	0.42
W-07 June*	210	0.73	0.40

* Same sample subdivided before shipping to lab.

b) Interlaboratory Comparison

		Parameter	
Laboratory	U (ppb)	Ra-226 (Bq/L)	Pb-210 (Bq/L)
Monenco (08 June)	255	0.65	-
SRC (08 June)	270	1.0	-
Monenco (12/13 June)	-	-	L 0.7
SRC (12/13 June)	-	-	0.3

TABLE 6.4.13: INTERLABORATORY AND REPEATABILITY COMPARISONS FOR NON-RADIONUCLIDE PARAMETERS FOR GUNNAR

	Barringer W-6 June	BEAK 6 June	BEAK 7 June	Barringer W-12 June	BEAK 12 June
Al	0.02	0.32		L 0.01	0.24
B	0.289	0.36/0.28		0.213	0.30
Ba	0.015	0.02		0.011	0.02
Be	L 0.0005	L 0.01		L 0.0005	L 0.01
Ca	188	194		213	200
Cd	L 0.01	0.010		L 0.01	L 0.005
Co	L 0.05	0.02		L 0.05	0.02
Cr	0.01	0.02		0.01	0.02
Cu	0.010	0.010		L 0.008	0.010
Fe	0.26	0.60		0.64	0.72
K	3	3.9		2	4.2
Mg	163	180		168	183
Mn	3.25	3.3		6.07	6.1
Mo	L 0.2	0.03		L 0.2	0.03
Na	48	49		49	51
Ni	L 0.05	0.02		0.05	0.01
Pb	L 0.05	0.10		L 0.05	0.09
Si (as SiO_2)	12.8	13.9		13.7	14.1
Sr	0.412	0.48		0.433	0.49
Ti	0.011	0.15		0.016	0.17
V	0.124	0.01		0.132	0.01
Zn	L 0.05	0.020		L 0.05	0.020
pH		7.4	7.6		
Conductivity		1,900	1,950		
Alkalinity		27	25		
Dissolved Solids		1,870	1,880		
F^-		0.4	0.4		
Cl^-		60	74		
NO_3^-		L 2	L 5		
PO_4^{3-}		L 0.1	L 5		
NO_3^-		L 0.2	L 0.5		
SO_4^{3-}		1,090	1,040		

TABLE 6.4.14a: RADIONUCLIDES INTERLABORATORY COMPARISON FOR JUNE-JULY SAMPLES FOR LACNOR SAMPLES

		Th-230 (Bq/L)	Ra-226 (Bq/L)	Th-232 (Bq/L)	Th-228 (Bq/L)
SW-01	Monenco	4.1	0.89	1.1	1.4
	SRC	3.5	2.5	1.7	1.7
	Chemex	4.9	1.72	0.64	0.64
SW-02	Monenco	2.2	0.84	0.33	1.1
	SRC	1.5	3.0	1.9	2.0
	Chemex	2.8	2.1	0.43	0.43
SW-03	Monenco	1.2	0.88	0.18	0.16
	SRC	1.2	1.1	0.25	0.25
	Chemex	2.0	1.0	0.20	0.20

TABLE 6.4.14b: INTERLABORATORY COMPARISON OF RADIONUCLIDES FOR OCTOBER SAMPLE FOR LACNOR

		Pb-210 (Bq/L)
SW-O1	Monenco	2
	Chemex	1.43
SW-02	Monenco	L 1
	Chemex	0.38
SW-03	Monenco	L 1
	Chemex	0.91

TABLE 6.4.15a: BLIND REPLICATE OF RADIONUCLIDES FOR JULY SAMPLE BY MONENCO FOR LACNOR SAMPLES

Date	U (ppm)	Th-230 (Bq/L)	Ra-226 (Bq/L)	Pb-210 (Bq/L)	Po-210 (Bq/L)	Th-232 (Bq/L)	Ra-228 (Bq/L)	Th-228 (Bq/L)
SW-01								
25 July*	0.500	17.7	1.0	2.8	1.5	4.9	L 1	2.0
31 July*	0.490	25.0	1.8	2.8	1.2	3.1	1.9	2.0
SW-02								
25 July*	0.077	3.1	0.56	L 1	0.17	0.45	L 1	0.70
31 July*	0.125	3.4	0.74	L 1	0.25	0.41	L 1	0.83
SW-03								
27 July*	0.033	0.88	0.64	L 1	0.24	0.12	L 1	0.13
31 July*	0.034	1.0	0.82	L 1	0.27	0.13	L 1	0.11

* Labelled as date given.

TABLE 6.4.15b: BLIND REPLICATE OF RADIONUCLIDE FOR OCTOBER SAMPLE BY MONENCO FOR LACNOR SAMPLE

Station	U (ug/L)	Th-230 (Bq/L)	Ra-226 (Bq/L)	Pb-210 (Bq/L)	Th-232 (Bq/L)	Th-228 (Bq/L)
SW-01	0.210	8.9	0.68	2	0.62	0.28
	0.215	8.5	0.64	L 1	0.63	0.32
SW-02	0.0895	2.2	0.49	L 1	0.21	0.24
	0.160	2.0	0.68	L 1	0.21	0.14
SW-03	0.123	4.1	0.46	L 1	0.38	0.28
	0.125	3.6	0.54	L 1	0.31	0.30

TABLE 6.4.16a SURFACE WATER - INTERLABORATORY COMPARISON OF CATIONS FOR 15 APRIL SAMPLE (UNITS: mg/L)

	SW-01		SW-02		SW-03		
	Barringer(1)	BEAK	Barringer(1)	BEAK	Barringer(1)		BEAK
					Analysis (2)	Analysis (1)	
Ag	LT.05	0.02/L 0.01	.005	L 0.01	0.005	LT.005	0.03
Al	22.6	19.9	15.5	12.5	7.79	8.44	7.5
B	.019	0.11	.131	0.34	L 0.004	.008	0.04
Ba	.007	L 0.01	LT.005	L 0.01	0.009	.009	0.01
Be	.0014	L 0.01	.0014	L 0.01	0.0005	.0008	L 0.01
Ca	153	131	223	210	60.6	63.9	52
Cd	.03	0.05/0.05	.07	0.17	L 0.01	.01	0.03
Co	.16	0.15/0.16	.18	0.22	0.11	.15	0.11
Cr	LT.01	0.04/0.04	LT.01	0.07	0.03	.02	0.04
Cu	.130	0.12/0.12	.068	0.06	0.048	.051	0.05
Fe	182	152	700	590	110	108	94
K	4	4.2	19	20	4	5	4.4
Mg	19.9	19.7	83.3	80	17.7	18.3	16.9
Mn	.92	0.83/0.82	6.16	5.5	0.93	1.05	0.87
Mo	LT.2	0.06	LT.2	0.11	L 0.2	LT.2	0.03
Na	2	4.5	18	20	4	4	5.2
Ni	.14	0.16/0.16	.11	0.19	0.10	.10	0.08
Pb	LT.05	0.24/0.24	LT.05	0.32	L 1	LT.05	0.16
Si	17.5	14	17.8	14	6.63	7.31	5.5
Sv	.171	0.16	.430	0.42	0.073	.079	0.08
Ti	.020	0.13	.039	0.21/0.22	0.024	.025	0.10
V	.017	0.02	.005	0.03	0.015	.006	0.01
Zn	.13	0.12/0.12	LT.05	0.13	0.06	LT.05	0.04

Notes

1 Samples analyzed December 1985.
2 Sample Analyzed May-June, 1985.

TABLE 6.4.16b: INTERLABORATORY COMPARISON OF CATIONS FOR 29 APRIL SAMPLE FOR LACNOR TAILINGS RUNOFF

	SW-01		SW-02		SW-03	
	Barringer	BEAK	Barringer	BEAK	Barringer	BEAK
Ag	L 0.005	L 0.01	L 0.005	L 0.01	L 0.005	L 0.01/L 0.01
Al	38.6	32/32	10.1	8.7	1.15	0.67/0.66
B	0.603	0.2/0.1	0.391	0.10/0.09	0.025	0.03
Ba	0.007	0.01/0.01	0.012	0.01	0.008	L 0.01/L 0.01
Be	0.0028	L 0.01/L 0.01	0.0011		L 0.0005	
Ca	250	210/240	102	82	15.4	12.3/13.6
Cd	0.02	0.06	L 0.01	0.04	L 0.01	L 0.01
Co	0.34	0.24	0.20	0.01	0.06	L 0.01
Cr	0.01	0.07	L 0.01	0.03	L 0.01	0.08
Cu	0.222	0.20	0.072	0.06	0.011	0.01
Fe	232	196	153	130	12.7	11.6
K	5	5.4/5.2	7	6.7	1	0.54/0.52
Mg	27.1	28/28	23.5	23	2.38	2.1/2.1
Mn	1.21	1.09	1.63	1.42	0.14	0.12
Mo	L 0.2	0.05/0.08	L 0.2	0.03	L 0.2	L 0.01/L 0.01
Na	6	6.0/7.0	6	6.0	1	1.0/1.2
Ni	0.11	0.26	0.11	0.10	L 0.05	L 0.01
Pb	L 0.05	0.28	L 0.05	0.21	L 0.05	0.02
Si (SiO_2)	56	44/43	19.1	15.4	3.8	3.2/3.1
Sr	0.263	0.24/0.25	0.150	0.13	0.018	0.01/0.02
Ti	0.043	0.19	0.018	0.10	L 0.005	0.04
V	L 0.005	0.02/0.03	0.008	0.01	0.008	L 0.01/L 0.01
Zn	0.19	0.18	0.07	0.07	L 0.05	L 0.01

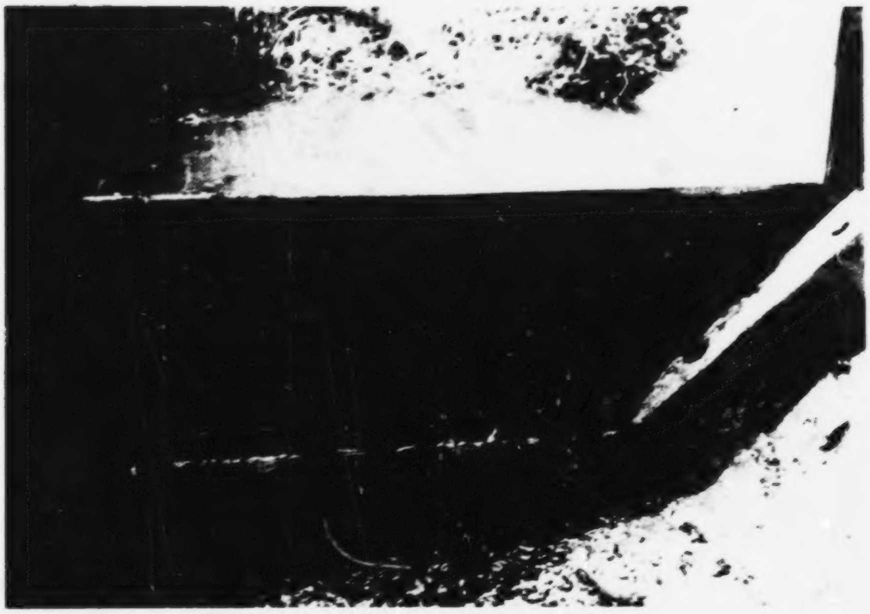
TABLE 6.4.16c: INTERLABORATORY COMPARISON OF NON-RADIONUCLIDE PARAMETERS FOR 19 JULY SAMPLE OF LACNOR TAILINGS RUNOFF

	SW-01		SW-02		SW-03	
	Barringer+	BEAK+	Barringer	BEAK	Barringer	BEAK
Ag	L 0.005	L 0.01	L 0.005	0.02	L 0.005	L 0.01
Al	26.8	17.6	17.7	13.2	9.40	8.2
As	L 1	8	L 1	8	-	L 1
B	0.011	0.28	L 0.004	0.61/0.59	L 0.004	0.02
Ba	0.005	0.01	0.008	0.02	0.030	0.03
Be	0.0015	L 0.01	0.0013	L 0.01	L 0.0005	L 0.01
Ca	401	410	407	430	50.1	46
Cd	L 0.01	0.10	L 0.01	0.21	L 0.01	L 0.005
Co	0.23	0.26	0.29	0.40	0.10	0.08
Cr	0.27	0.06	0.57	0.07	0.02	L 0.01
Cu	0.052	0.045	0.054	0.040	0.037	0.030
Fe	634	600	1,380	1,280	22	18.9
K	10	11.4	35	36	3	2.9
Mg	52.4	51	139	141	11.9	11.2
Mn	2.44	2.3	11.2	10.6	0.82	0.72
Mo	1.1	0.10	2.2	0.15	L 0.2	0.10
Na	5	10.2	31	37	3	2.9
Ni	0.21	0.26	0.13	0.29	0.10	0.09
Pb	L 0.05	0.51	L 0.05	0.67	L 0.05	0.02
Si (as SiO_2)	57	50	45	38	20	18.5
Sr	0.394	0.41	0.693	0.69	0.072	0.08
Ti	0.043	0.23	0.064	0.28	0.005	0.04
V	0.063	0.03	0.123	0.05	0.010	L 0.01
Zn	0.14	0.14	0.11	0.14	0.11	0.10
TP	0.117	L 0.02*	0.093	L 0.02*	0.14	0.008
Kjel N	3.17	3.5	5.19	7.2	0.24	0.80
Nitrate N		2.3**		3.6**		0.8/0.9**
F^- (mg/L)	1.15	1.9	1.56	3.1	0.128	0.3
Cl^-	2.16	4.9	10.7	22/22	0.60	1.4/1.6
NO_2^-	L 0.2	1.2	L 0.2	0.6	L 0.02	0.3
PO_4^{3-}	L 1	L 1	L 1	L 1	L 0.1	L 1
NO_3^-	L 0.5	L 1	L 0.5	L 1	L 0.05	L 0.1
SO_4^{2-}	2,280	1,700	4,020	4,500	323	310

* Low recovery on spikes; sample interference.

** Iron interference.

+ Labelled as 11 July to Barringer, 19 July to BEAK.



(i) View of Weir in Upstream Direction

(ii) Channel from Gunnar Main

FIGURE 6.1.1 Surface Water Photographs

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LOCATION MAP FOR
SURFACE WATER STUDIES

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE
DRAWN BY
DATE
APPROVED BY

FIGURE 6.1.1

FIGURE 6.1.2

Sketch of Weir Looking Upstream Toward Gunnar Main

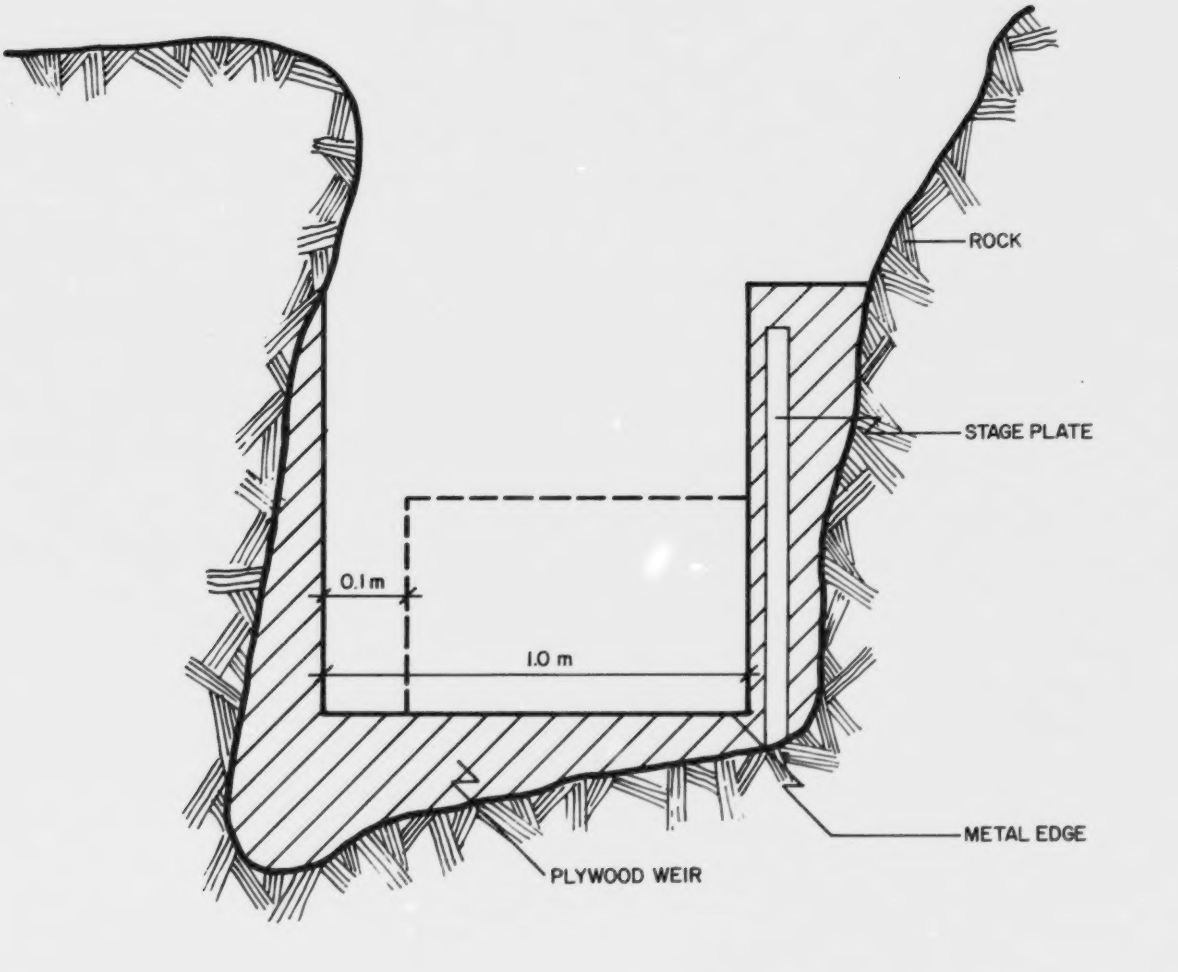

ROCK
STAGE PLATE
0.1 m
1.0 m
METAL EDGE
PLYWOOD WEIR
INSERT USED AFTER JUNE 22

FIGURE 6.1.3

Cumulative Runoff Measured and Estimated at the Weir

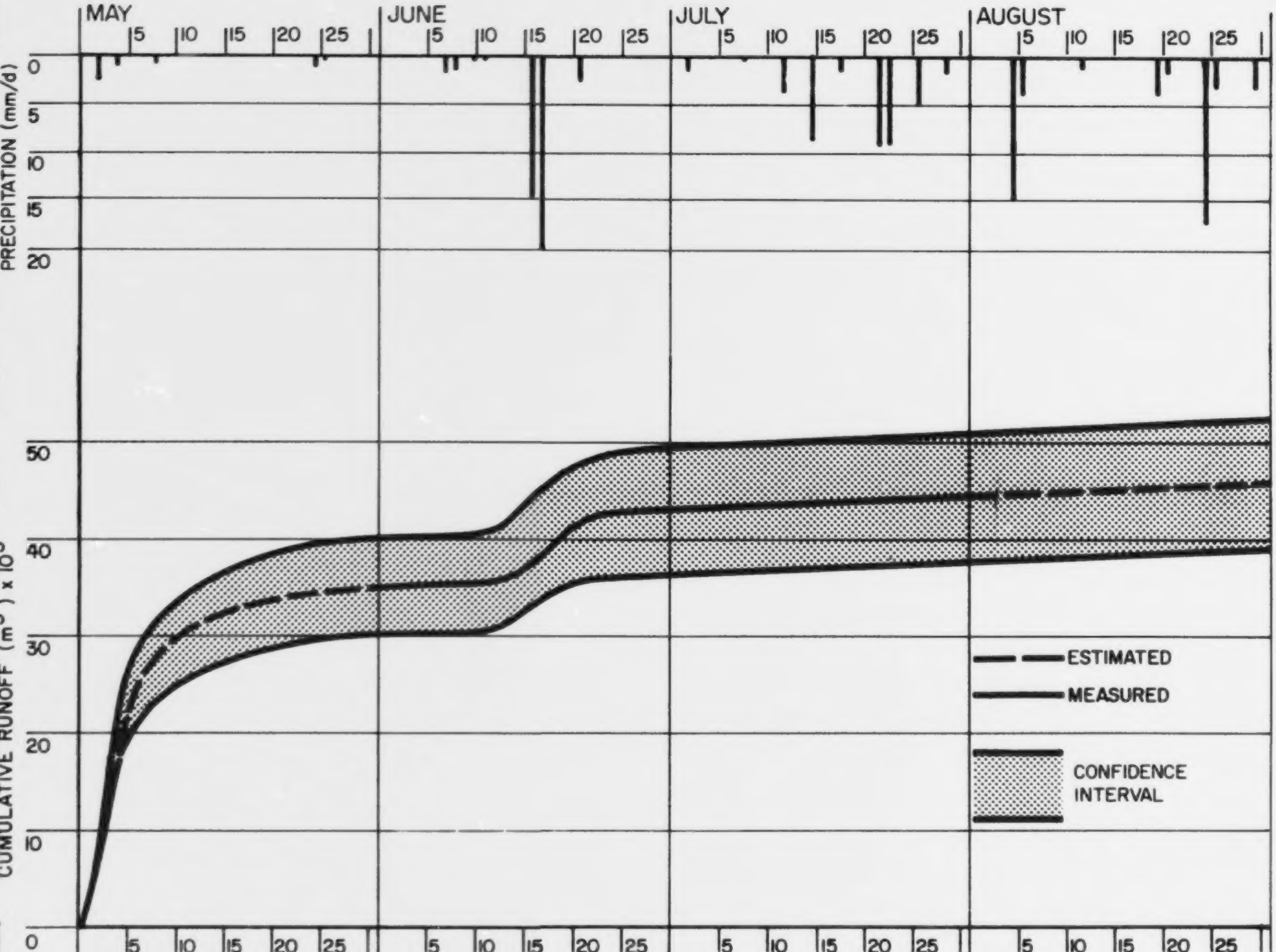


FIGURE 6.1.4 Plot of Flow Rate with Time at the Weir

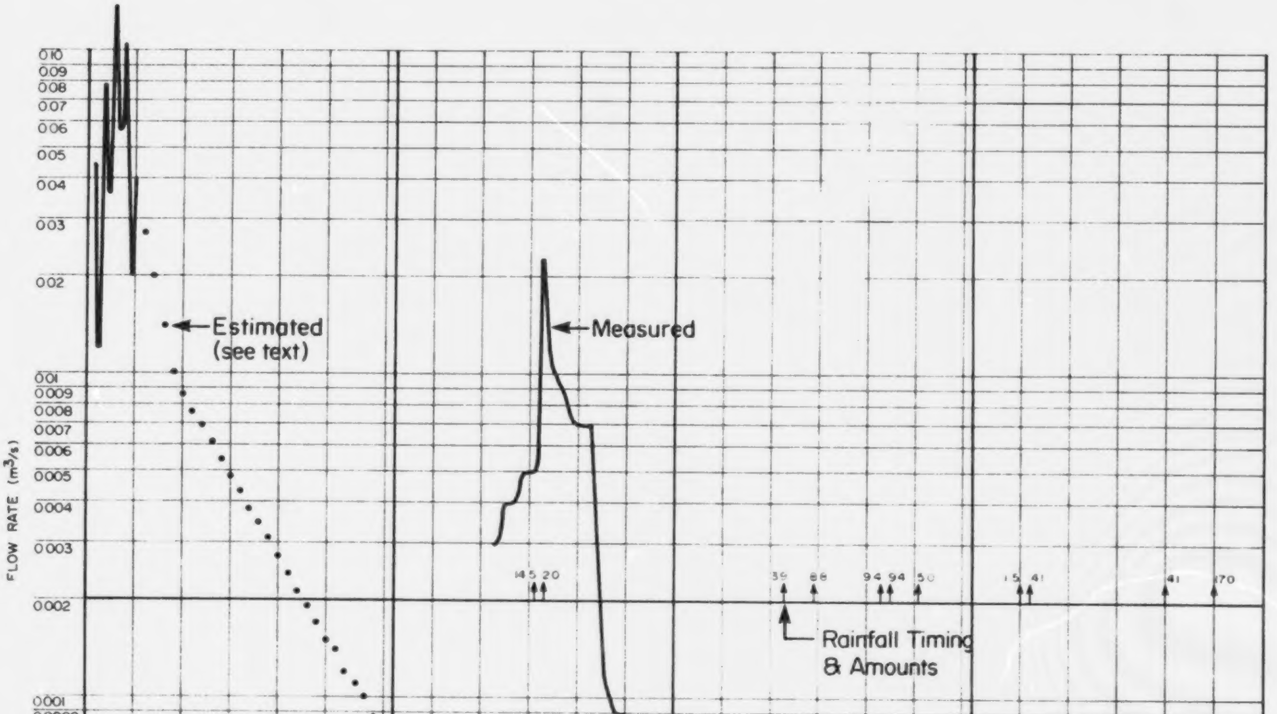
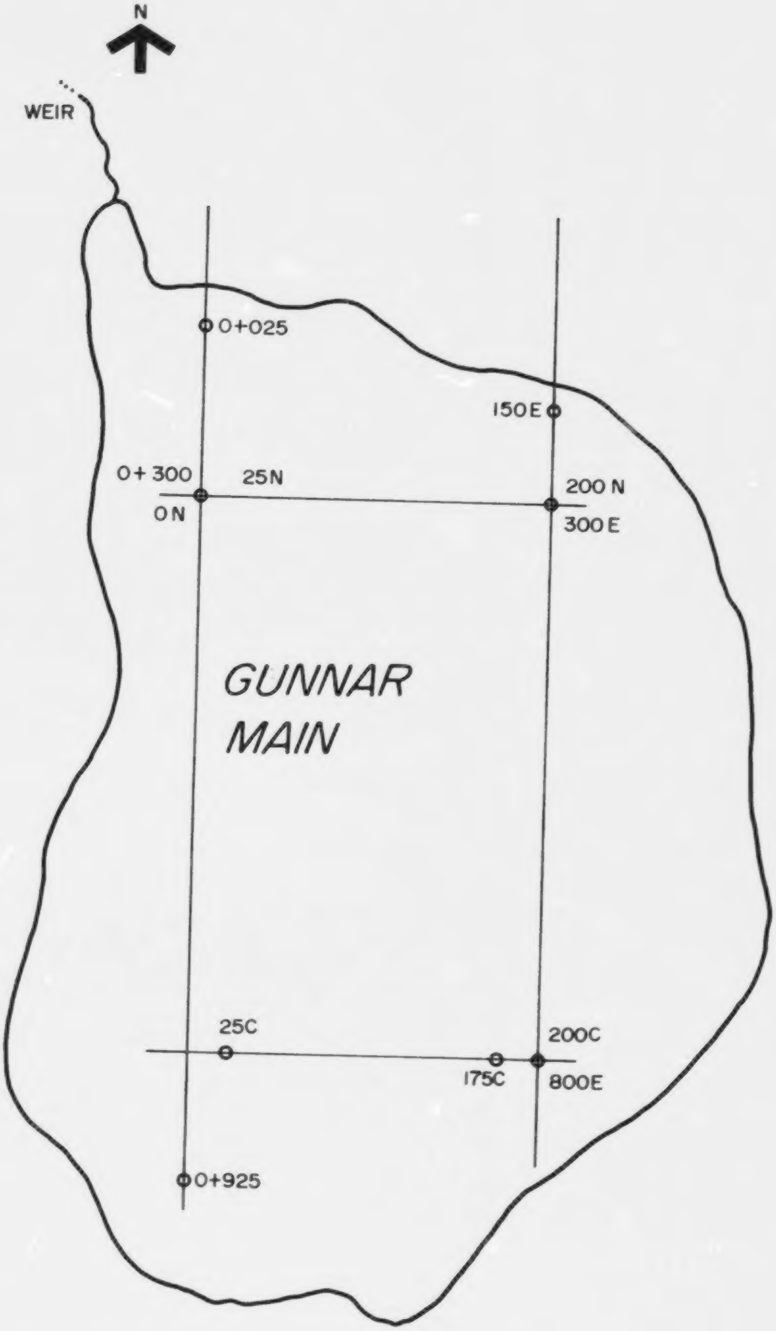


FIGURE 6.2.1 Grid for Snow Cores Taken on March 21 on Gunnar Main


N
WEIR
0+025
150E
0+300
25N
0N
200N
300E
GUNNAR
MAIN
25C
200C
175C
800E
0+925

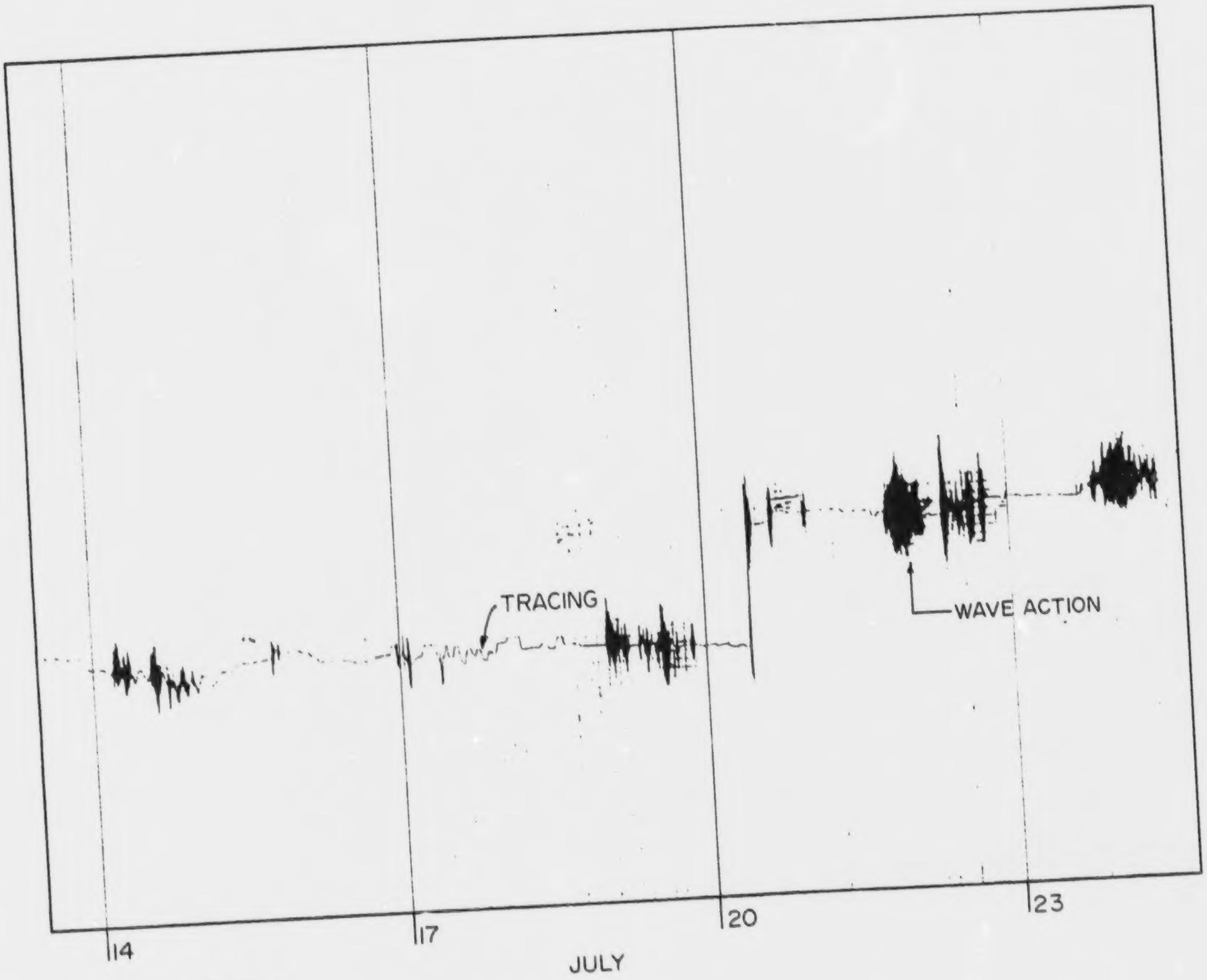


FIGURE 6.3.1a

Portion of Langley Bay Chart from Water Level Records

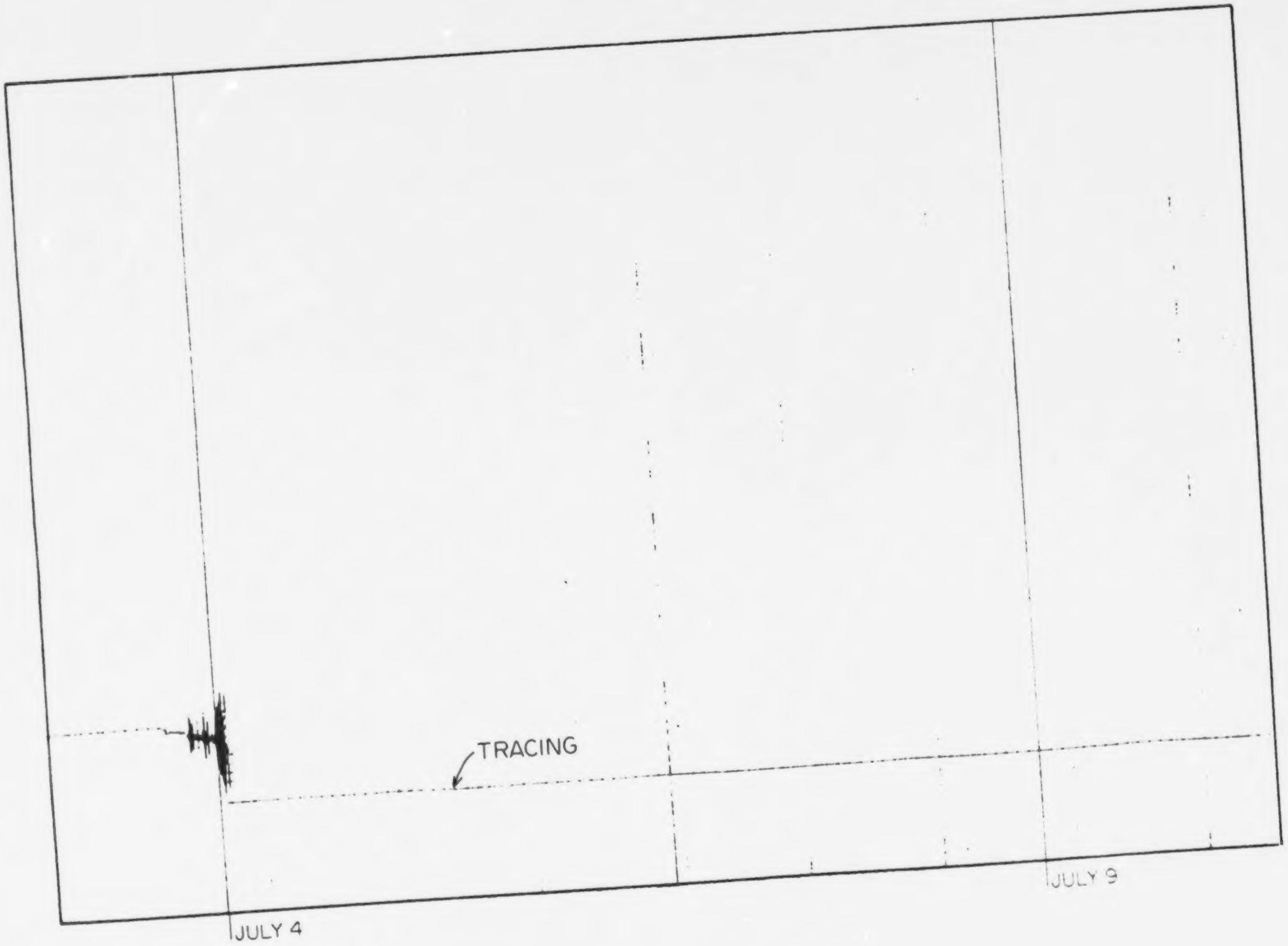


FIGURE 6.3.1b

Portion of Cut-off Langley Bay Chart from Water Level Recorders

FIGURE 6.3.2: SKETCH OF HYDROLOGIC PATHWAYS OF GUNNAR-LANGLEY BAY

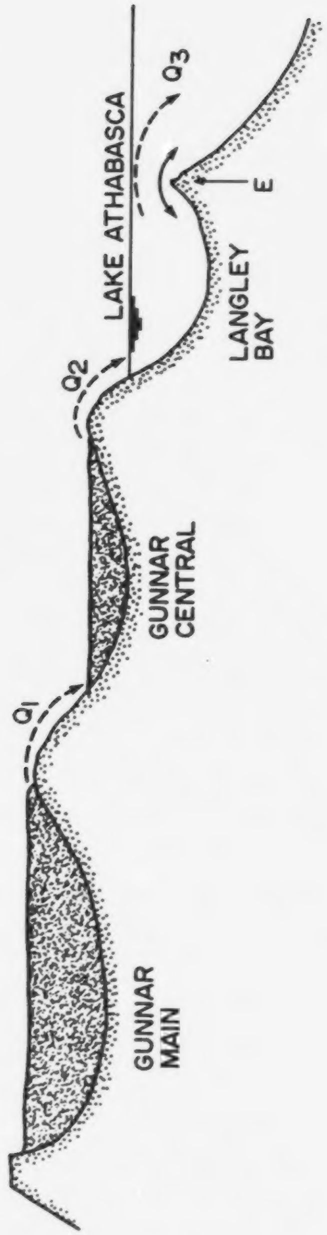
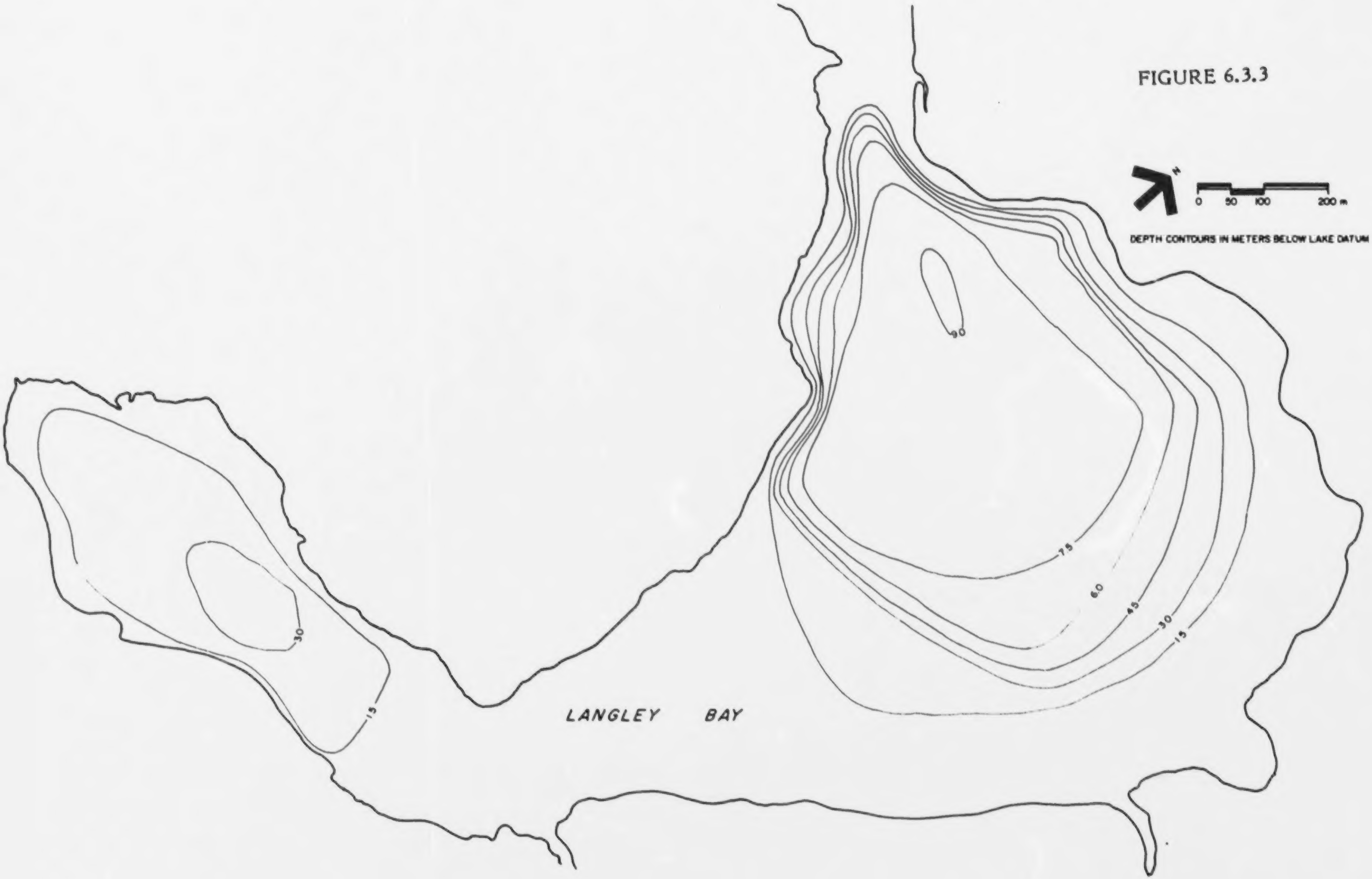

GUNNAR MAIN
Q1
GUNNAR CENTRAL
Q2
LAKE ATHABASCA
LANGLEY BAY
E
Q3

FIGURE 6.3.3


0
50
100
200 m
DEPTH CONTOURS IN METERS BELOW LAKE DATUM
N
90
75
6.0
4.5
3.0
1.5
LANGLEY BAY
3.0
1.5

Volume

7

CONTRACT REPORT NUMBER: OSQ84-00195
VOLUME 7

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
CONTRACT NO. 55SQ.2341-4-1674X
Volume 7
Biology

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+ slides

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THE GUNNAR FIELD STUDY

The Gunnar Field Study consists of 10 volumes, each published separately. Volumes 2 to 10 are supplements to Volume 1, written as Appendices 1 to 9.

The 10 volumes are:

- Volume 1 - Summary Report
- Volume 2 - Test Procedures and QA/QC Program (Appendix 1)
- Volume 3 - Atmospheric Studies (Appendix 2)
- Volume 4 - Tailings Solids and Surround Soils (Appendix 3)
- Volume 5 - Groundwater (Appendix 4)
- Volume 6 - Surface Water (Appendix 5)
- Volume 7 - Biology (Appendix 6)
- Volume 8 - Waste Rock (Appendix 7)
- Volume 9 - Eating Habits of Local Population (Appendix 8)
- Volume 10 - Permafrost (Appendix 9)

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EXECUTIVE SUMMARY

Biology

A number of previous studies and reports have described aquatic and terrestrial biota of the Gunnar tailings and surrounding environment. Harms and Fraser (1982) describe plant communities on the tailings, giving frequency, abundance and percent cover for plant species in each community. Redmann and Frankling (1982) give a plant species inventory and associated tailings chemistry. Kalin (1981) provides data on trace metal content of tailings vegetation, and associated chemistry of tailings and standing water. Kalin (1982) gives plant species densities and selected radionuclide contents (Ra-226, Pb-210), with additional data on chemistry of associated tailings. Tailings vegetation studies have concentrated on Gunnar Main, while also providing limited data for Gunnar Central and Langley Bay. Data on uranium and thorium isotopes in vegetation, and vegetation biomass, are lacking from previous reports, as are data of any kind from the Waste Rock Pile and the Frog Pond between Gunnar Main and Gunnar Central. These data may be important for validation of food chain transport and mass balance models.

Previous studies of aquatic biota in the Gunnar area include an EPS (1981) study in Langley Bay and Lake Athabasca, and Tone's (1982) SRC study of the Gunnar Flooded Pit and Lake Athabasca. The EPS report provides data on fish catch, fish radionuclide contents (Ra-226, Pb-210, Th-230), associated water and sediment chemistry, plankton and benthic insect densities, and plankton biomass. Tone's report provides data on fish catch, fish radionuclide contents (Ra-226, Pb-210) associated water and sediment chemistry, and densities of benthic invertebrates, plankton and sediment bacteria. Comparable bacterial data for the tailings are lacking from past reports.

The biology component of the present study was designed to compile and evaluate existing data and to augment these data with additional sampling and analysis to provide a more complete biological description of the Gunnar site. The 1985 field survey included collection and analysis of bacterial samples at various depths in two tailings cores, description of vegetational communities and their distribution on the tailings, determination of above-ground biomass in each community, collection and analysis of 19 vegetation samples for trace metals and radionuclides, and collection and analysis of five associated root zone soil samples for trace metals radionuclides and grain size. Radionuclide analyses included U-238, Ra-226, Th-230, Th-232, Th-228 and Pb-210. Sampling sites included the Waste Rock Pile, Gunnar Main, the Frog Pond, Gunnar Central and Langley Bay, as well as several terrestrial control sites. Eighteen additional vegetation samples collected in 1983 by M. Apps of the Northern Forest Research Station, were analyzed for trace metals and radionuclides as part of this study. Both in 1983 and 1985, vegetation and soil samples were archived for future use.

Additional water, sediment and fish samples collected by EPS in 1983 for analysis of trace metals and radionuclides are described as part of this study although analytical results were not available at the time of report preparation. Local terrestrial wildlife and wild food consumption habits of Gunnar area residents were determined by consultation with local residents and conservation authorities.

Tailings bacterial densities were determined in aerobic, anaerobic, sulphur-reducing, sulphur-oxidizing and iron oxidizing categories. Bacterial densities in all categories were higher in Langley Bay tailings than on Gunnar Main (Table 1). In both locations aerobic bacterial maxima occurred at the tailings surface, and in the original lake sediments about 4 m below the surface, with minimum densities in the deepest tailings zone. Anaerobic bacteria followed a similar pattern as on Gunnar main, but no strong depth relationship to those on Langley Bay. Other bacterial groups achieved maximum density in the original lake sediments on Gunnar Main, or in the deep tailings on Langley Bay.

Vegetation communities on the tailings included a peripheral mesic shrub community, a grass and/or sedge community (depending on tailings moisture), a cattail or cattail-sedge community near standing water, and a mud-flat community on recently drained tailings. A xeric shrub community characterized the Waste Rock Pile. Dominant plant taxa and peak (August) biomass estimates for each community are shown in Table 2. The sedge community of the Frog Pond is the most productive and the xeric shurb community of the Waste Rock Pile is the least productive. Community distributions on the tailings are shown in Figure 1.

TABLE 1: BACTERIAL COUNTS IN GUNNAR TAILINGS (bacteria/g dry weight of material)

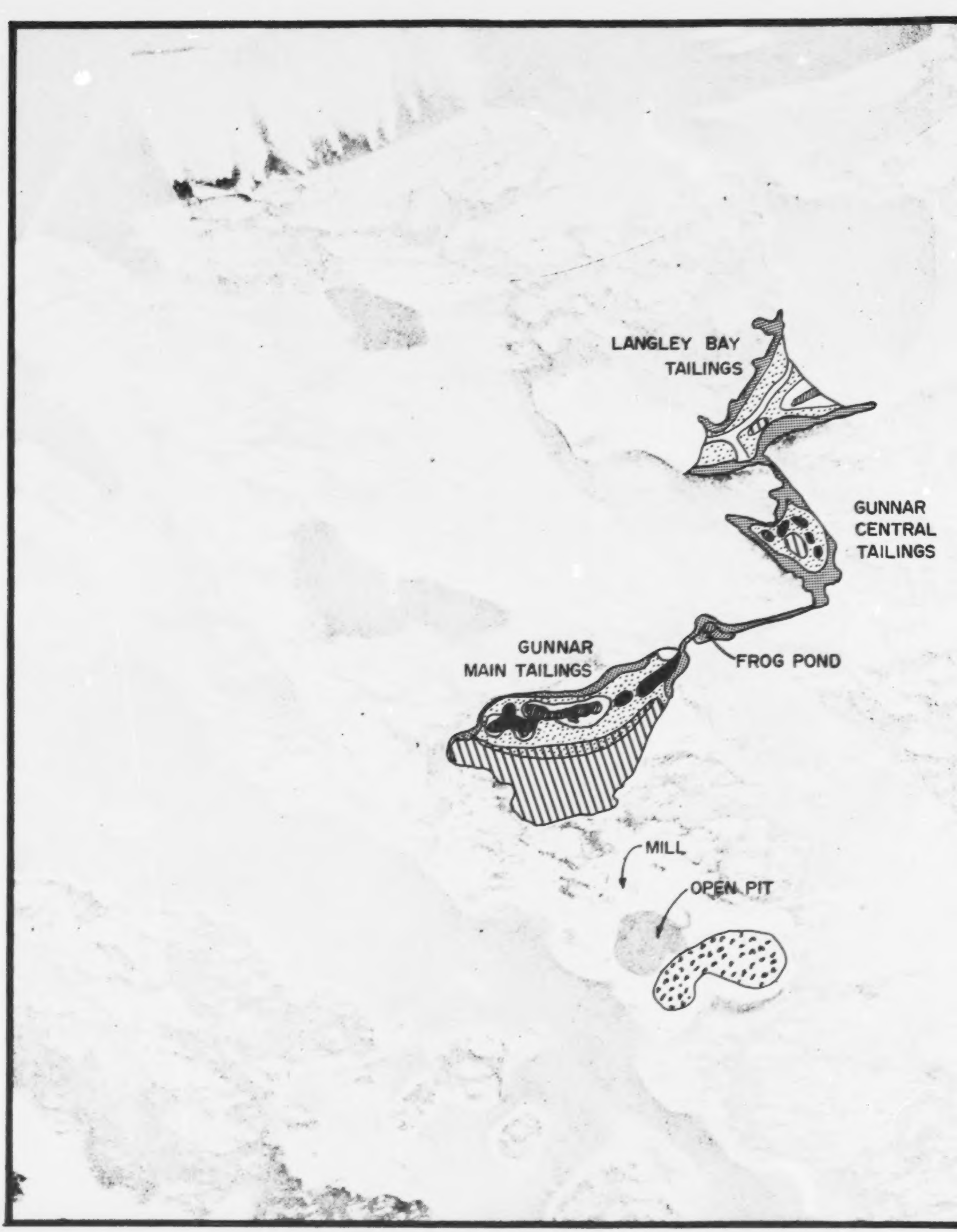
Sampling Location and Date	Core Hole Number	Sample Depth (m)	Soil Description	Aerobic Bacteria (bacteria/g)*	Anaerobic Bacteria (bacteria/g)*	Sulphate Reducing Bacteria MPN/g	Sulphur Oxidizing Bacteria MPN/g	Iron Oxidizing Bacteria MPN/g
Gunnar Main (06.12.84)	N3E	0-0.03	Tailings	$4.8x10^2$	$4.9x10^3$	23	L 3	L 3
		1.06-1.22	Tailings	$1.4x10^2$	$3.3x10^2$	17	L 3	L 3
		2.44-2.74	Tailings	L 100	$3.9x10^2$	2	L 3	L 3
		4.42-4.57	Lake Sediment	$3.3x10^2$	$2.1x10^3$	49	23	23
Langley Bay (24.03.85)	2B-1	0-0.20	Tailings	$1.7x10^6$	$6.0x10^4$	$2.4x10^4$	L 3	9
	2B-2	0.13-0.45	Tailings	$2.7x10^4$	$1.1x10^5$	$1.6x10^4$	230	$2.4x10^5$
	2C	3.4	Tailings	$5.5x10^3$	$9.9x10^4$	$3.5x10^3$	230	$9.3x10^3$
	2C	3.9	Lake Sediment	$2.1x10^6$	$1.6x10^5$	230	230	930

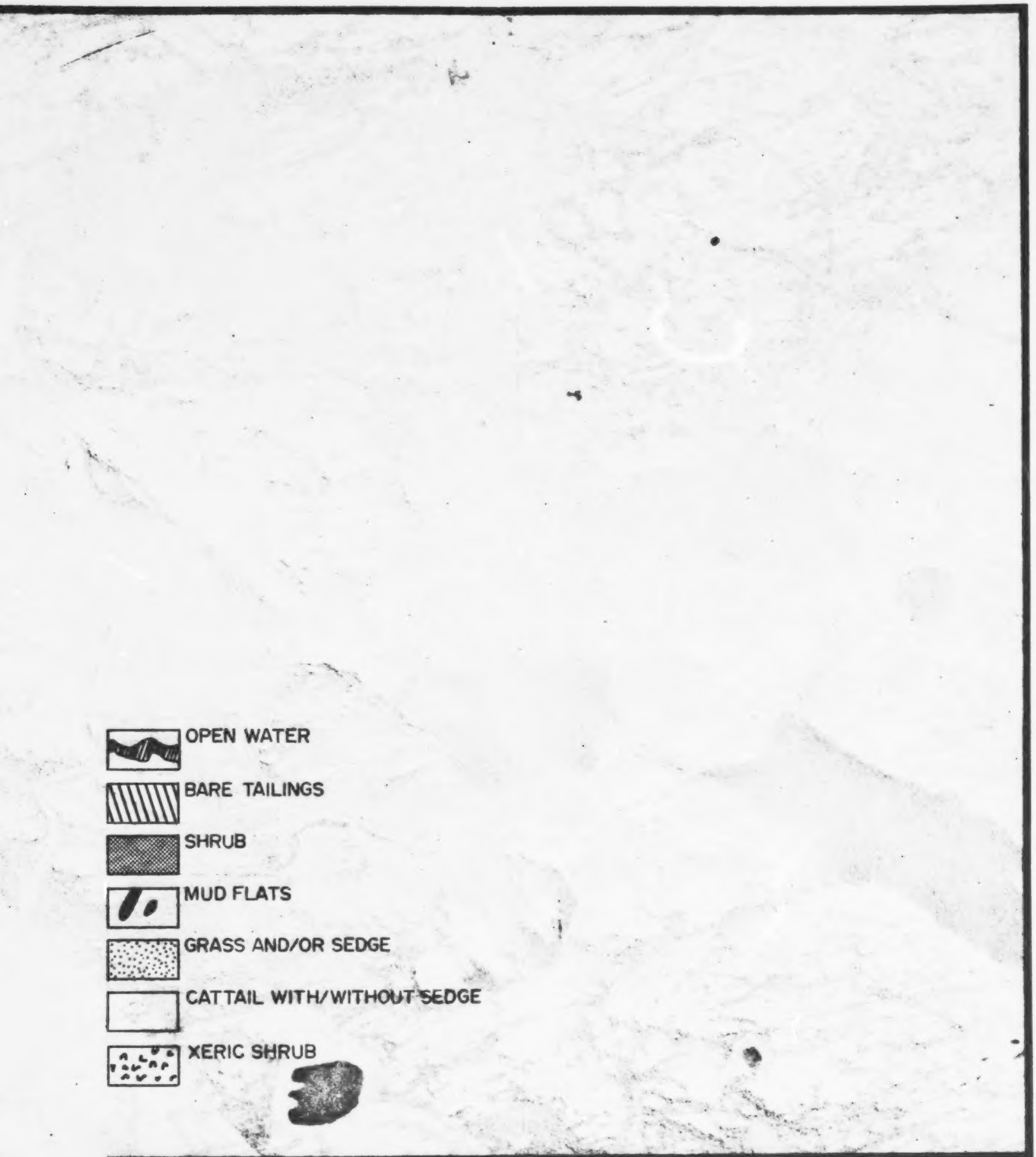
MPN = Mean probable number, estimated from numbers of positive tubes in dilution series (FDA, 1977).

* Bacteria/g based on colony counts.

TABLE 2: VEGETATION BIOMASS IN GUNNAR TAILINGS AND WASTE ROCK AREAS

Location-Community	Dominant Taxa	Biomass (gm dry wt/m^2)
Frog Pond - Shrub	*Alnus*, *Salix*, *Betula*	101.25±77.14
Frog Pond - Sedge	*Carex aquatilis*	329.04±81.21
Langley Bay - Grass	*Deschampsia*, *Pucinellia*	125.8±266.1
Langley Bay - Shrub	*Alnus*, *Salix*, *Betula*	96.39±83.63
Langley Bay - Cattail/Sedge	*Typha*, *Carex*	226.21±77.73
Gunnar Main - Grass	*Hordeum*, *Pucinellia*	67.42±78.07
Gunnar Main - Shrub	*Alnus*, *Salix*, *Betula*	82.66±41.07
Gunnar Main - Mud Flat	*Juncus*	65.44±34.41
Gunnar Main - Cattail	*Typha latifolia*	118.17±82.13
Gunnar Central - Shrub	*Alnus*, *Salix*, *Betula*	93.66±65.51
Gunnar Central - Mud Flat	*Juncus*	41.54±46.89
Gunnar Central - Grass/Sedge	*Calamagrostis*, *Carex*	76.59±67.00
Waste Rock - Shrub	*Salix*, *Populus*, *Rubus*	18.66±21.37


LANGLEY BAY TAILINGS
GUNNAR CENTRAL TAILINGS
GUNNAR MAIN TAILINGS
FROG POND
MILL
OPEN PIT


OPEN WATER
BARE TAILINGS
SHRUB
MUD FLATS
GRASS AND/OR SEDGE
CATTAIL WITH/WITHOUT SEDGE
XERIC SHRUB

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SCALE	DRAWN BY PMG	FIGURE I
DATE 30·01·86	APPROVED BY	

The greatest radionuclide levels in above-ground vegetation were found in grasses near water and sedges on Gunnar Main (in particular Hordeum jubatum and Carex aquatilis), sedges and willow (Salix interior) on Langley Bay and the Frog Pond, and in cattails (Typha latifolia) near the Gunnar Flood Pit and the mouth of Zemel Creek. Lichens (Cladonia amouracraea) on rock ridges in the vicinity of Gunnar Main also contained high radionuclide levels, as did a single spruce sample (Picea mariana) with a high Ra-226 activity. Table 3 shows the range of radionuclide levels in dominant vegetation from each tailings area, based on the pooled set of samples from 1983 and 1985 vegetation surveys.

Radionuclide levels in root zone soils from each tailings area, based on the 1985 survey, are shown in Table 4. Bioaccumulation factors, based on analysis of 3 soil samples which correspond exactly to locations of analyzed vegetation samples, were on the order of 10^{-3} to 10^{-2} for U-238 and Ra-226, $\leq 10^{-1}$ for Th-232 and Th-228, $\leq 10^{-3}$ for Th-230 and approximately 10^{-2} for Pb-210.

TABLE 3: RANGE OF RADIONUCLIDE LEVELS IN DOMINANT PLANT SPECIES FROM GUNNAR TAILINGS AND VICINITY, 1983 - 1985

Location	No. of Samples	U-238[1] ppm	Ra-226 Bq/g	Th-232 Bq/g	Th-230 Bq/g	Th-228 Bq/g	Pb-210 Bq/g
Gunnar Main[1]	11	< 0.2-91.9	0.05-2.4	< 0.01-0.38	< 0.01-0.84	< 0.01-0.38	0.16-2.1
Gunnar Central[1]	6	0.4-12.5	0.05-0.48	< 0.01	0.02-0.17	< 0.01-0.48	0.2-1.1
Langley Bay[1]	7	< 0.2-10.0	0.06-0.45	< 0.01	< 0.01-0.12	< 0.01-0.01	0.02-0.8
Frog Pond	3	< 0.2-1.2	0.06-0.12	< 0.01	< 0.01	< 0.01	0.27-0.74
Control 1	3	< 0.2-0.8	< 0.01-0.14	< 0.01	< 0.01-0.03	< 0.01-0.02	0.31-0.88
Control 2	3	< 0.2	< 0.01-0.03	< 0.01	< 0.01	< 0.01	0.32-0.34
Zemel Creek	1	0.6	0.06	< 0.01	< 0.01	< 0.01	0.48
Flooded Pit	2	< 0.2-1.4	0.11-0.14	< 0.01	< 0.01	< 0.01	0.24

---

[1] U-238 maxima on tailings are from 1983 samples (M. Apps, Northern Forest Research Station), minima from 1985 samples (this study); higher values in 1983 samples may be related to differences in sample preparation (1983 samples washed in the field; 1985 samples washed in the laboratory within four days of collection).

TABLE 4: RANGE OF RADIONUCLIDE LEVELS IN ROOT ZONE SOIL SAMPLES FROM GUNNAR TAILINGS, 1985

Location	No. of Samples	U-238 ppm	Ra-226 Bq/g	Th-232 Bq/g	Th-230 Bq/g	Th-228 Bq/g	Pb-210 Bq/g
Gunnar Main	2	83.5-95.8	7.9-9.9	0.10-0.16	5.6-10.7	0.26-0.32	7.2-8.8
Gunnar Central	1	41.1	4.6	0.04	3.2	0.30	5.8
Langley Bay	1	50.2	14.0	0.22	6.4	0.25	11.8
Frog Pond	1	64.4	34.0	0.22	14.0	0.74	10.0

VOLUME 7

Biology

7.1 BACTERIA

7.1.1 Field Procedures

As shown on Map 7.1.1, two cores were collected from the tailings for bacterial analysis. Sample location numbers correspond to borehole numbers. These cores, plus three others, were collected as part of the geotechnical field program. Core N3E was collected on 06 December 1984, while cores LB2 (B and C) were collected between 22 to 24 March 1985. All cores were sub-divided by depth in the field. Depth ranges of samples provided for analysis were not continuous, but rather represented a range of depths from the tailings surface to the underlying lake sediments. All samples were shipped frozen to the laboratory.

7.1.2 Laboratory Procedures

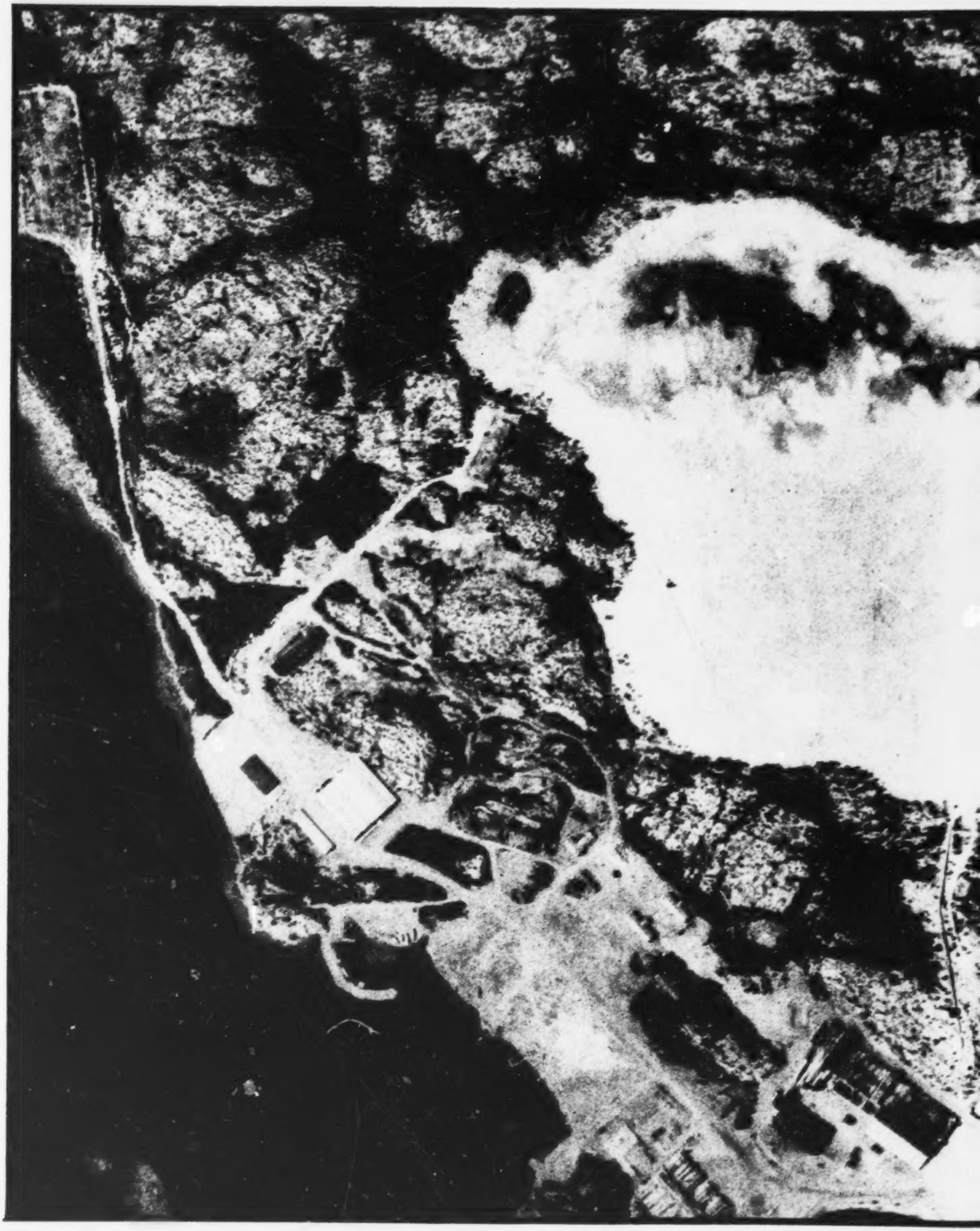
Cores N3E from Gunnar Main and Cores 2B and 2C from Langley Bay were selected for bacterial analysis. Analyses were performed by Dr. Colin Mayfield of the University of Waterloo. Analyses performed on each core subsample included:

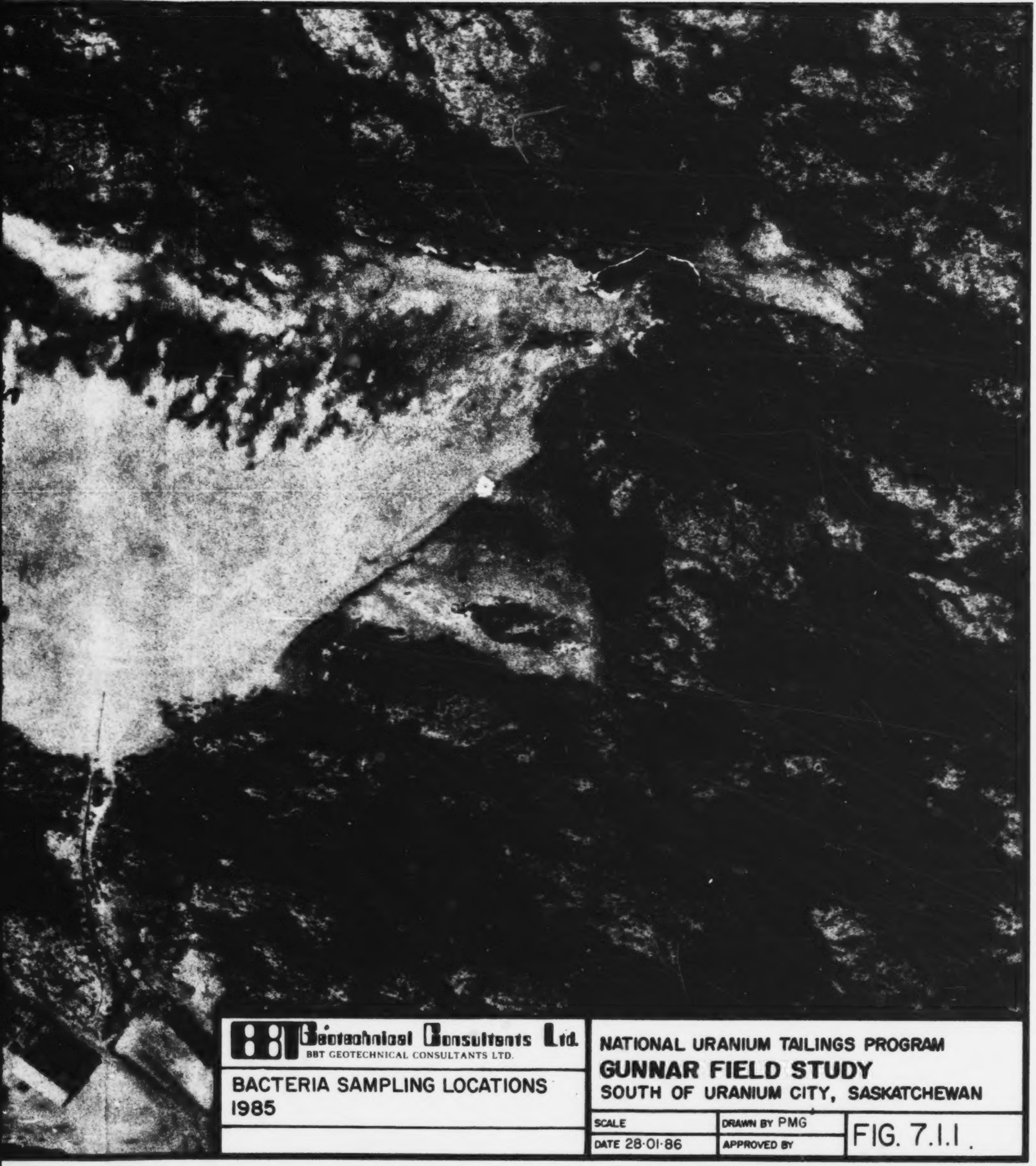
- o Aerobic Plate Counts
- o Anaerobic Deep Tube Counts
- o Sulphate Reducing Bacteria Count
- o Most Probable Number Sulphur-Oxidizers Estimate
- o Most Probable Number Iron Oxidizers Estimate

The methods used to isolate and count the different categories of bacteria in the samples are briefly described below.

7.1.2.1 Aerobic Plate Counts

Samples were diluted in sterile 0.85% saline and decimal serial dilution prepared. Aliquots of 0.1 mL were transferred to the surface of soil extract agar plates (1 kg of soil





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BACTERIA SAMPLING LOCATIONS
1985

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE	DRAWN BY PMG	FIG. 7.1.1 .
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LB2

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BACTERIA SAMPLING LOCATIONS
1985

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE	DRAWN BY PMG	FIG. 7.1.1
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autoclaved in 1 L of 100 mL standard soil extract medium added to 900 mL distilled water plus yeast extract (0.5 g), ferric phosphate (0.01 g), glucose (2.5 g) and agar (15 g)). The plates were incubated at 25°C for 7 to 14 days and the colonies counted.

7.1.2.2 Anaerobic Deep Tube Counts

Sterile test tubes were filled with Reinforced Clostridial Medium (Difco) and made anaerobic by evacuation and refilling with nitrogen gas. The tubes were steamed before use to melt the agar and maintained at 45°C to keep the agar molten.

Samples were sampled anaerobically under a stream of nitrogen gas and transferred to a flask containing anaerobic diluent (Baar's medium). Dilutions were made in diluent and quantities transferred to the deep agar tubes. After incubation at 25°C for 14 days, the colonies within the deep agar tubes were counted and expressed as "numbers of anaerobic bacteria per gram".

7.1.2.3 Sulphate Reducing Bacteria Count

Samples were taken in the same way as for Anaerobic Deep Tube Counts. Samples were diluted in Baar's medium and incubated in deep thin tubes with Baar's medium solidified with agar (see Pankhurst, STET, 1971. "The isolation and enumeration of sulphate-reducing bacteria". In: Isolation of Anaerobes, Shapton & Board (Eds.). Academic Press, London and New York). The tubes were incubated for 30 days at 25°C and the number of black colonies (sulphate-reducing bacterial colonies) were counted. The MPN method was used to estimate the number of sulphate-reducing bacteria in the original sample based on the dilution series and the presence or absence of black colonies in the tubes.

7.1.2.4 Most Probable Number (MPN) Sulphur-Oxidizers Estimate

Sulphur-oxidizing media was prepared with elemental sulphur powder (0.1 g per 10 mLs) as follows:

1. weigh out 0.1 g quantities of elemental sulphur powder per test tube (the sulphur will not dissolve in the media so it must be weighed separately (Tuttle et al., 1968)).
2. make up the following modified nine K medium (Silverman and Lundgren, 1959):

	Per Litre
K_2HPO_4	0.5 g
$Ca(NO_3)_2 * 4H_2O$	0.01 g
$(NH_4)_2 SO_4$	3.0 g
KCl	0.1 g
$MgSO_4 * 7H_2O$	0.5 g
Distilled H_2O	1,000 mL

3. adjust the pH of the nine K medium to 3.0 with sterile H_2SO_4. Dispense 10 mL of nine K medium per tube and sterilize in flowing steam for one hour on three successive days.

The aerobic sample-taking and dilution procedure is identical to that outlined under the aerobic plate count method. The dilutions were selected so that a series of tubes yielded all positives at the lower dilution and all negatives at the higher dilution. After the dilutions were made, using a 1 mL pipetman, 1 mL of the appropriate dilution was transferred into each of three test tubes containing sulphur-oxidizing media. Five dilution series consisting of three tubes each were innoculated.

When setting up the sulphur-oxidizing MPN, it is advantageous to set up both positive and negative controls, so that comparisons to these controls can be made during the evaluation of the MPN tubes. For the positive control, 1 mL of a pure culture of Thiobacillus thiooxidans was added to each of four test tubes containing sulphur-oxidizing media. The negative control consisted of four test tubes of sterile sulphur-oxidizing media.

All tubes were incubated at 25°C for three weeks (Harrison, 1978; Tuttle et al., 1968). After incubation, the tubes were observed and compared against the positive and negative controls. The elemental sulphur of the positive control dropped to the bottom of the tube with growth, as compared with the sterile control, where it floated on top of the media. This was one indication of growth, but a pH indicator dye was also used to observe a pH change in the medium during growth. Two drops of a 1% solution of basic fuchsin was then added to each tube. The controls were used as examples of positive and negative colours. The negative tubes gave a cherry red colour, and the positive tubes gave a purple colour (basic fuchsin is purple at pH 1.2 to 1.5 and red at 1.5 to 3.0).

The most probable number (MPN) method was used to estimate the number of viable sulphur-oxidizing bacteria present in the sample. To obtain the MPN, the number of positive tubes from each of three selected dilutions was determined and referred to an MPN table (FDA, 1977) giving MPN estimates and 95% confidence intervals.

7.1.2.5 Most Probable Number (MPN) Iron Oxidizers Estimate

Iron oxidizing media was prepared as follows:

Solution No. 1	per Litre
K_2HPO_4	0.5 g
$Ca(NO_3)_2 * 4H_2O$	0.01 g
$(NH_4)_2 SO_4$	3.0 g
KCl	0.1 g
$MgSO_4 * 7H_2O$	0.5 g
Distilled H_2O	800 mL
Solution No. 2	
$FeSO_4 * 7H_2O$	44.0 g
Distilled H_2O	200 mL

1. adjust the pH of Solution No. 1 to 3.0 with sterile sulphuric acid and place in the Agamatic automatic sterilizer and dispenser (New Brunswick Scientific Company) to be sterilized.
2. adjust the pH of Solution No. 2 to 3.0 with sterile sulphuric acid, and filter sterilize. Note: This solution is rusty coloured when oxidized and stains clothes, hands, etc.; also, allow quite a lot of time for filter sterilization (0.45 micron filter).
3. when the Agarmatic is tempered (55°C), aseptically add Solution No. 2 through the injection port using a sterile 50 mL syringe. Then dispense approximately 10 mL per test tube. (Alternate method: sterilize Solution No. 1 in the autoclave (8 mL per test tube) and then aseptically add 2 mL of filter sterilized Solution No. 2 to each tube).

The aerobic sample-taking and dilution procedure is identical to that outlined under the aerobic plate count method. The dilutions were selected so that a series of tubes yielded all positives at the lower dilution and all negatives at the higher dilution. After the dilutions were made, using a 1 mL volume pipetman, 1 mL of the appropriate dilution was transferred into each of three test tubes containing iron oxidizing media. Five dilutions series, consisting of three tubes each, were innoculated.

The iron oxidizing media will gradually chemically oxidize over time so both positive and negative controls make evaluation of the tubes much easier. For the positive control, 1 mL of a pure culture of Thiobacillus ferroxidans was added to each of four test tubes containing iron oxidizing media.

All tubes were incubated at 25°C for three weeks (Harrison, 1978; Tuttle et al., 1968).

After incubation, the tubes were observed and compared against the positive and negative controls. The positive controls had flakes of heavy dark red-brown precipitate near the top on the sides of the test tube. The negative control tubes and those tubes in which growth did not occur had a light yellow-brown precipitate due to autooxidation.

The most probable number (MPN) method was used to estimate the number of viable sulphur oxidizing bacteria present in the sample. To obtain the MPN and 95% confidence interval, the number of positive tubes from each of three selected dilutions was determined and referred to an MPN table (FDA, 1977).

7.1.2.6 References

FDA. 1977. MPN Table. FDA Bacteriological Analytical Manual, Appendix D. June 1977.

Harrison, Arthur P. 1978. Microbial succession and mineral leaching in an artificial coal spoil. Appl. Environ. Microbiol. 36: 861-869.

Silverman, M.P. and D.G. Lundgren. 1959. Studies on the chemoautotrophic iron bacterium Ferrobacillus ferrooxidans. I. An improved medium and a harvesting procedure for securing high cell yields. J. Bacteriol. 77: 642-647.

Tuttle, J.H., C.I. Randles and P.R. Dugan. 1968. Activity of microorganisms in acid mine water. I. Influence of acid water on aerobic heterotrophs of a normal stream. J. Bacteriol. 95: 1495-1503.

7.1.3 QA/QC Program

Samples were transferred to sterile diluent in a laminar flow hood. This prevents atmospheric contamination. This method is normally only used in biotechnology research procedures but was applied to this study as an extra precaution for contamination control. Diluents were checked for sterility. Some plates were also set aside uninnoculated to check for contamination. Normal bacterial laboratory aseptic methods were followed to ensure sterility of all equipment used. No replicate samples were measured.

7.1.4 Data Presentation

The data are presented in Table 7.1.1. All results are presented as the number of bacterial cells per gram dry weight of material. Aerobic and anaerobic counts are total numbers of bacteria per gram of sample. The sulphate reducers, sulphur oxidizers and

TABLE 7.1.1: BACTERIAL COUNTS IN GUNNAR TAILINGS (bacteria/g dry weight of material)

Sampling Location and Date	Core Hole Number	Sample Depth (m)	Soil Description	Aerobic Bacteria (bacteria/g)*	Anaerobic Bacteria (bacteria/g)*	Sulphate Reducing Bacteria MPN/g	Sulphur Oxidizing Bacteria MPN/g (95% Confidence Interval)	Iron Oxidizing Bacteria MPN/g
Gunnar Main (06.12.84)	N3E	0–0.03	Tailings (Red)	4.8×10^{2}	4.9×10^{3}	23 (7-70)	L 3 (-)	L 3 (-)
		1.06–1.22	Tailings (Red)	1.4×10^{2}	3.3×10^{2}	17 (5-46)	L 3 (-)	L 3 (-)
		2.44–2.74	Tailings (Red)	L 100	3.9×10^{2}	2 (L 0.5-7)	L 3 (-)	L 3 (-)
		4.42–4.57	Lake Sediment (Grey)	3.3×10^{2}	2.1×10^{3}	49 (17-130)	23 (4-120)	23 (4-120)
Langley Bay (24.03.85)	2B-1	0–0.20	Tailings (Reddish Brown)	1.7×10^{6}	6.0×10^{4}	2.4×10^{4} (-)	L 3 (-)	9 (1-36)
	2B-2	0.13–0.45	Tailings (Reddish Brown)	2.7×10^{4}	1.1×10^{5}	1.6×10^{4} $(6.4\times10^{3}-5.8\times10^{4})$	230 $(40-1.2\times10^{3})$	2.4×10^{5} $(1.5\times10^{4}-4.8\times10^{5})$
	2C (2-2)	3.4	Tailings (Reddish Brown)	5.5×10^{3}	9.9×10^{4}	3.5×10^{3} $(1.2\times10^{3}-1.0\times10^{4})$	230 (70-700)	9.3×10^{3} $(1.5\times10^{3}-3.8\times10^{4})$
	2C (2-1)	3.9	Lake Sediment (Grey)	2.1×10^{6}	1.6×10^{5}	230 (70-700)	230 $(4-1.2\times10^{3})$	930 $(150-3.8\times10^{3})$

MPN = Mean probable number, estimated from numbers of positive tubes in dilution series (FDA, 1977).

(-) = Confidence interval could not be derived due to very low or high numbers.

* = Bacteria/g based on colony counts.

—— = Summer water table.

iron oxidizers are presented as estimates derived from Most Probable Number (MPN) counts per gram of material. For these MPN counts, the 95% confidence limits are quoted in brackets. Where sample counts were either very low or very high, the 95% confidence interval could not be determined.

7.2 VEGETATION

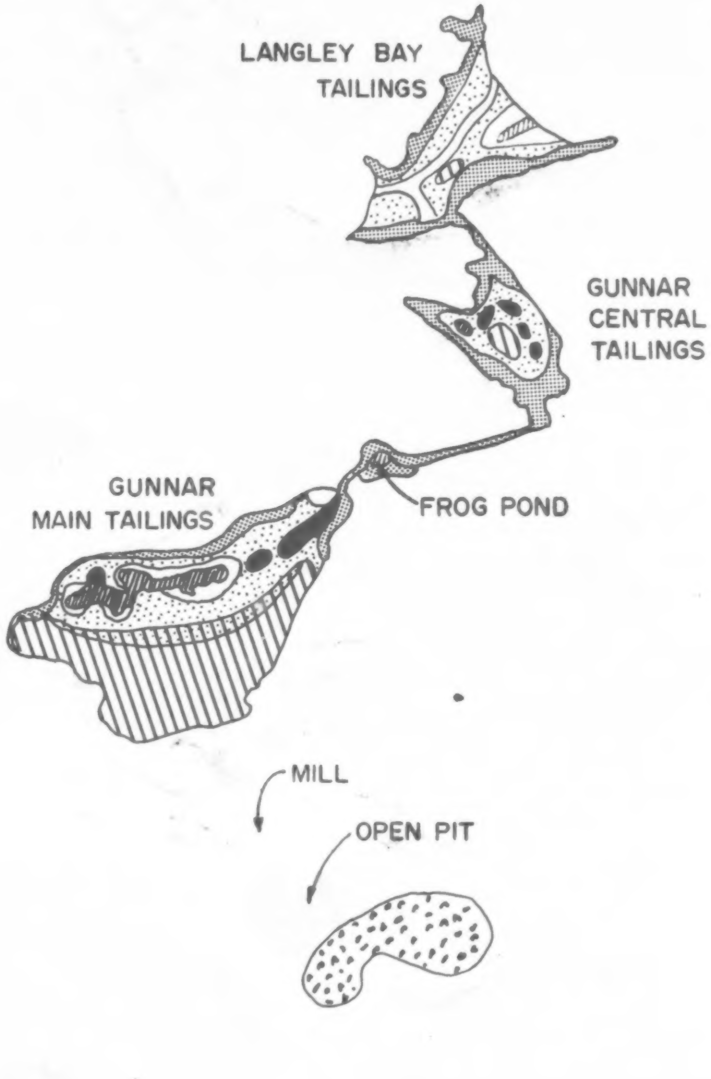
7.2.1 Biomass

7.2.1.1 Field Procedures

Above-ground biomass samples were collected from vegetation communities on Gunnar Main, Gunnar Central, the Frog Pond, Langley Bay and the Waste Rock pile. The location of each community is shown on Map 7.2.1. Photographs of some communities are included in Section 7.8. Community distributions were typically defined by clear demarkations between plant species groups, often related to tailings moisture or stability. Vegetation communities sampled and their dominant taxa include:

		Photographic Plate
Gunnar Main:	Grass (Hordeum, Pucinellia)	7.8.1, 7.8.2
	Shrub (Alnus, Salix, Betula)	7.8.1
	Mud Flat (Juncus)	7.8.3
	Typha (Typha latifolia)	7.8.1
Frog Pond:	Shrub (Alnus, Salix, Betula)	7.8.4
	Sedge (Carex)	7.8.4
Gunnar Central:	Shrub (Alnus, Salix, Betula)	
	Mud Flat (Juncus)	
	Grass Sedge (Calamagrostis, Carex)	7.8.5
	Typha (Typha latifolia)	
Langley Bay:	Shrub (Alnus, Salix, Betula)	
	Grass (Deschampsia, Pucinellia)	7.8.6
	Sedge Typha (Carex, Typha)	7.8.6
Waste Rock Pile:	Shrub (Populus, Rubus)	7.8.7

Samples were collected during the week of 01 August 1985. Peak biomass generally occurs in northern temperate and subarctic regions of Canada during mid to late


LANGLEY BAY
TAILINGS
GUNNAR
CENTRAL
TAILINGS
GUNNAR
MAIN TAILINGS
FROG POND
MILL
OPEN PIT

GUNNAR
CENTRAL
TAILINGS
D

- 〰 OPEN WATER
- ▨ BARE TAILINGS
- ▩ SHRUB
- ● MUD FLATS
- ⁘ GRASS AND/OR SEDGE
- ☐ CATTAIL WITH/WITHOUT SEDGE
- ⁖ XERIC SHRUB

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VEGETATION COMMUNITIES

NATIONAL URANIUM TAILINGS PROGRAM
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SCALE	DRAWN BY PMG	FIG. 7.2.1
DATE 30·01·86	APPROVED BY	

August. In each community, vegetation was collected from ten randomly placed quadrats of 0.25 m^2 dimension. A photograph of the quadrat is included in Section 7.8 as Plate 7.8.8. In each quadrat, all living plant matter was clipped at ground level and placed in paper bags. Samples were air-dried prior to shipping.

7.2.1.2 Laboratory Procedures

All samples were oven-dried at 70°C for 24 hours and weighed to the nearest 0.1 g. Weights were converted to dry weight/m^2.

7.2.1.3 QA/QC Program

Ten replicate samples were collected from each community to determine the variation associated with biomass estimates.

7.2.1.4 Data Presentation

Biomass data are presented in Table 7.2.1. For each community, individual replicate values are presented as grams of dry weight/m^2.

7.2.2 Radionuclides and Trace Metals

7.2.2.1 Field Procedures

Samples of dominant plant species were collected during the 1985 field survey from each vegetation community in each tailings area for radionuclide and trace metal analysis. Forty samples were collected, nineteen were submitted for radionuclide analysis and six were submitted for analysis of trace metals. Sample locations are shown on Map 7.2.2. Each sample was collected as a composite of at least several plants. Only above-ground portions were included. All samples, except lichens, were washed in the laboratory, prior to analysis, within four days of collection.

Thirty-four vegetation samples were collected from in and around the tailings areas in 1983 by M. Apps (Northern Forest Research Station, Edmonton). Locations of these samples are included on Map 7.2.2. Eighteen samples were analyzed for radionuclides and ten were analyzed for trace metals. Most of the samples analyzed were aboveground plant parts. One root sample was included for comparison. All 1983 samples were washed in the field using Lake Athabasca water prior to shipping to the laboratory.

7.2.2.2 Laboratory Procedures

Vegetation samples were analyzed for uranium and thorium series radionuclides by MONENCO Analytical Laboratories (U-238 (1985 samples), Ra-226, Th-232, Th-230, Th-228 and Pb-210) and by M. Apps, Northern Forest Research Station (U-238, 1983 samples). Uranium-238 measurements reported by MONENCO were performed by delayed neutron activation at Atomic Energy of Canada Ltd. Uranium-238 measurements reported by M. Apps were performed by gamma ray neutron activation at the University of Alberta Slowpoke Facility. Vegetation samples were air-dried, ground and dessicated prior to analyses.

Methods for other radionuclides follow Chiu and Dean (1984). Radium-226 and thorium isotopes were determined by high resolution alpha spectrometry following pyrosulphate fusion. Lead-210 was determined indirectly by measurement of Bi-210 using a beta-counter, following pyrosulphate fusion.

Trace metals were determined by decoupled plasma emission scan (Spectrometrics, Inc., undated) of wet ashed plant tissues (Smith, 1965).

7.2.2.3 QA/QC Program

MONENCO's internal quality assurance program includes one replicate analysis per batch of 15 to 20 samples, one or two standards per batch, and one certified reference sample (EPA, NBS or CANMET) per batch. In addition, a tracer is added to every sample to check recovery. Barium-133 and Th-234 are used for determination of Ra-226 and thorium isotopes.

TABLE 7.2.1: VEGETATION BIOMASS IN GUNNAR TAILINGS AND WASTE ROCK AREAS

Sample No., Community	Location	Dry Weight (gm)	Biomass (gm dry weight/m^2)
M-Grass-1	Gunnar Main	2.1	30.1
M-Grass-2		0.0	0.0
M-Grass-3		1.6	24.1
M-Grass-4		0.0	0.0
M-Grass-5		3.2	47.6
M-Grass-6		4.0	58.7
M-Grass-7		15.0	221.2
M-Grass-8		8.1	119.7
M-Grass-9		11.8	172.8
M-Grass-10		0.0	0.0
Mean±S.D.		4.58±5.31	67.42±78.07
M-Shrub-1	Gunnar Main	3.4	50.6
M-Shrub-2		7.5	110.9
M-Shrub-3		10.0	147.6
M-Shrub-4		6.7	99.1
M-Shrub-5		7.1	105.0
M-Shrub-6		2.4	35.9
M-Shrub-7		3.6	53.5
M-Shrub-8		5.1	75.6
M-Shrub-9		8.5	124.9
M-Shrub-10		1.6	23.5
Mean±S.D.		5.59±2.79	82.66±41.07
M-Mud Flat-1	Gunnar Main	2.0	28.7
M-Mud Flat-2		7.0	102.2
M-Mud Flat-3		4.8	70.6
M-Mud Flat-4		4.4	64.7
M-Mud Flat-5		2.7	39.0
M-Mud Flat-6		4.9	71.3
M-Mud Flat-7		4.7	68.4
M-Mud Flat-8		9.4	138.2
M-Mud Flat-9		1.9	27.9
M-Mud Flat-10		3.0	43.4
Mean±S.D.		4.48±2.33	65.44±34.41
M-Cattail-1	Gunnar Main	6.5	95.6
M-Cattail-2		5.1	75.0
M-Cattail-3		8.4	122.8
M-Cattail-4		0.0	0.0

TABLE 7.2.1: VEGETATION BIOMASS IN GUNNAR TAILINGS AND WASTE ROCK AREAS

Sample No., Community	Location	Dry Weight (gm)	Biomass (gm dry weight/m^2)
M-Cattail-5		7.3	106.6
M-Cattail-6		14.0	205.9
M-Cattail-7		14.3	209.6
M-Cattail-8		8.8	129.4
M-Cattail-9		16.1	236.8
M-Cattail-10		0.0	0.0
Mean±S.D.		8.05±5.59	118.17±82.13
F-Shrub-1	Frog Pond	5.8	84.6
F-Shrub-2		15.1	221.3
F-Shrub-3		15.4	225.7
F-Shrub-4		11.7	171.3
F-Shrub-5		3.5	51.5
F-Shrub-6		6.6	97.1
F-Shrub-7		4.4	64.7
F-Shrub-8		3.2	46.3
F-Shrub-9		1.7	24.3
F-Shrub-10		1.8	25.7
Mean±S.D.		6.92±5.25	101.25±77.14
F-Sedge-1	Frog Pond	18.0	264.7
F-Sedge-2		19.0	279.4
F-Sedge-3		23.0	337.5
F-Sedge-4		19.8	290.4
F-Sedge-5		22.9	336.8
F-Sedge-6		31.5	463.2
F-Sedge-7		17.9	263.2
F-Sedge-8		32.3	474.3
F-Sedge-9		23.1	339.0
F-Sedge-10		16.5	241.9
Mean±S.D.		22.40±5.52	329.04±81.21
Waste Rock-1	Waste Rock Pile	0.0	0.0
Waste Rock-2		0.0	0.0
Waste Rock-3		2.9	43.2
Waste Rock-4		4.0	59.4
Waste Rock-5		1.3	19.0
Waste Rock-6		0.0	0.0
Waste Rock-7		0.4	5.7
Waste Rock-8		0.0	0.0

TABLE 7.2.1: VEGETATION BIOMASS IN GUNNAR TAILINGS AND WASTE ROCK AREAS

Sample No., Community	Location	Dry Weight (gm)	Biomass (gm dry weight/m^2)
Waste Rock-9		2.3	34.4
Waste Rock-10		1.7	24.9
Mean±S.D.		1.26±1.44	18.66±21.37
C-Shrub-1	Gunnar Central	16.4	240.4
C-Shrub-2		6.4	94.1
C-Shrub-3		3.3	48.5
C-Shrub-4		4.6	66.9
C-Shrub-5		4.7	69.1
C-Shrub-6		4.3	62.5
C-Shrub-7		12.2	179.4
C-Shrub-8		1.9	27.2
C-Shrub-9		5.8	85.3
C-Shrub-10		4.3	63.2
Mean±S.D.		6.39±4.46	93.66±65.51
C-Mud Flat-1	Gunnar Central	3.2	47.1
C-Mud Flat-2		1.0	14.7
C-Mud Flat-3		2.1	30.9
C-Mud Flat-4		0.0	0.0
C-Mud Flat-5		1.9	27.2
C-Mud Flat-6		2.9	42.6
C-Mud Flat-7		2.2	31.6
C-Mud Flat-8		11.5	169.1
C-Mud Flat-9		2.4	34.6
C-Mud Flat-10		1.2	17.6
Mean±S.D.		2.84±3.19	41.54±46.89
C-Grass Sedge-1	Gunnar Central	1.1	16.2
C-Grass Sedge-2		3.1	45.6
C-Grass Sedge-3		5.1	75.0
C-Grass Sedge-4		2.6	37.5
C-Grass Sedge-5		5.0	73.5
C-Grass Sedge-6		12.0	176.5
C-Grass Sedge-7		14.1	207.4
C-Grass Sedge-8		0.0	0.0
C-Grass Sedge-9		4.0	58.8
C-Grass Sedge-10		0.7	10.3
C-Grass Sedge-11		8.3	121.3
C-Grass Sedge-12		7.7	113.2
Mean±S.D.		5.31±4.45	76.59±67.00

TABLE 7.2.1: VEGETATION BIOMASS IN GUNNAR TAILINGS AND WASTE ROCK AREAS

Sample No., Community	Location	Dry Weight (gm)	Biomass (gm dry weight/m^2)
L-Grass-1	Langley Bay	7.1	104.4
L-Grass-2		0.0	0.0
L-Grass-3		1.6	23.5
L-Grass-4		3.3	48.5
L-Grass-5		59.6	876.5
L-Grass-6		0.9	13.2
L-Grass-7		6.3	91.9
L-Grass-8		3.6	52.9
L-Grass-9		0.1	1.5
L-Grass-10		3.1	45.6
Mean±S.D.		8.56±18.09	125.8±266.1
L-Shrub-1	Langley Bay	14.4	211.8
L-Shrub-2		7.3	106.6
L-Shrub-3		6.5	95.6
L-Shrub-4		6.2	90.4
L-Shrub-5		17.0	250.0
L-Shrub-6		0.0	0.0
L-Shrub-7		8.8	129.4
L-Shrub-8		3.3	48.5
L-Shrub-9		0.4	5.1
L-Shrub-10		1.8	26.5
Mean±S.D.		6.57±5.68	96.39±83.63
L-Sedge Cattail-1	Langley Bay	18.9	277.2
L-Sedge Cattail-2		14.5	212.5
L-Sedge Cattail-3		16.0	253.3
L-Sedge Cattail-4		19.0	279.4
L-Sedge Cattail-5		12.5	183.1
L-Sedge Cattail-6		10.4	152.9
L-Sedge Cattail-7		25.0	366.9
L-Sedge Cattail-8		18.0	264.0
L-Sedge Cattail-9		6.5	94.9
L-Sedge Cattail-10		12.1	177.9
Mean±S.D.		15.29±5.26	226.21±77.73

MONENCO participates successfully in analysis check programs initiated by Environment Canada, CANMET, CCRMP, U.S. EPA Las Vegas and the Analytical Subcommittee of the Canadian Uranium Producers Metalurgical Committee.

Internal quality control at the Northern Forest Research Station included both repeat analysis (same analytical sample) and replicate analysis (different sample aliquot). Repeat analysis gave values always within the analytical precision (± 3 sigma for counting statistics) while the replicate samples usually gave higher variance, indicating a certain amount of sample inhomogeneity.

Four samples analyzed by MONENCO for uranium-238 were cross-checked by M. Apps at the Northern Forest Research Station. Uranium values reported by M. Apps for 1983 samples were one to two orders of magnitude higher than those reported by MONENCO for 1985 samples. Both sets of results indicate the same general pattern of uranium distribution with the highest uranium concentrations in Gunnar Main grass or sedge. The discrepancy in magnitude between years is not related to any consistent difference in sample distribution. The cross-check samples indicate good analytical agreement between laboratories.

Internal quality assurance associated with trace metal analyses by BEAK includes routine use of certified and standard reference materials (EPA, NBS, NRC), replicate analyses, and spiked samples to eliminate interferences and confirm recovery. Successful participation in interlaboratory studies involving metal determinations in biological tissues includes studies sponsored by Environment Canada and the International Joint Commission.

7.2.2.4 Data Presentation

Radionuclide data in vegetation samples from the 1983 and 1985 surveys are listed in Tables 7.2.2 and 7.2.3, respectively, with counting errors for all determinations which exceed the detection limit. Corresponding trace metal data are listed in Tables 7.2.4 and 7.2.5 with approximate detection limits for each parameter. The sample locations shown

TABLE 7.2.2: RADIONUCLIDES IN VEGETATION FROM GUNNAR TAILINGS AND VICINITY, 1983 (M. Apps, Northern Forest Research Station)

Monenco No.	Plant Species	Sample Identification	General Location	U-238 (ppm)	Ra-226 (Bq/g)	Th-232 (Bq/q)	Th-230 (Bq/g)	Th-228 (Bq/q)	Pb-210 (Bq/g)
RV 5693	Hordeum jubatum	GMV-BAR-1A	Gunnar Main	82.6±0.6	2.4±0.1	0.38±0.02	0.84±0.04	0.38±0.02	2.1±0.05
RV 5694	Pucinellia nutalliana	GMV-SALT-1A	Gunnar Main	82.6±0.5	0.46±0.03	≤ 0.01	0.06±0.01	0.03±0.01	0.54±0.05
RV 5695	Typha latifolia	GMV-TYPH-2A	Gunnar Main	1.4±0.3	0.10±0.01	≤ 0.01	0.02±0.01	0.03±0.01	0.31±0.05
RV 9696	Salix sp.	GMV-WIL-1A	Gunnar Main	2.5±0.1	0.14±0.01	≤ 0.01	0.02±0.01	≤ 0.01	0.16±0.05
RV 9697	Carex aquatilis	GMV-CAR-2A	Gunnar Main	91.9±0.7	0.56±0.04	≤ 0.01	0.33±0.02	0.18±0.01	1.5±0.05
RV 5698	Pucinellia nutalliana	GCV-PUC-1A	Gunnar Central	12.5±0.2	0.48±0.04	≤ 0.01	0.17±0.01	0.14±0.01	1.1±0.05
RV 5699	Carex aquatilis	GCV-CAR-1A	Gunnar Central	-	0.36±0.03	≤ 0.01	0.08±0.01	0.05±0.01	0.45±0.05
RV 5700	Pucinellia nutalliana	LBV-PUG-1A	Langley Bay	10.0±0.1	0.43±0.04	≤ 0.01	0.12±0.01	0.10±0.01	0.80±0.05
RV 5701	Salix sp.	LBV-WIL-1A	Langley Bay	1.06±0.08	0.07±0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.16±0.05
RV 5702	Deschampsia caespitosa	LBV-GRASS-1A	Langley Bay	0.95±0.06	0.26±0.02	≤ 0.01	0.05±0.01	0.06±0.01	0.50±0.05
RL 5703	Cladina alpestris	GMH-1-1	Gunnar Main	33.5±0.3	0.39±0.06	≤ 0.01	0.12±0.01	0.03±0.01	0.87±0.05
RL 5704	Cladonia amourocraea	GMH-2-2	Gunnar Main	67.3±0.7	1.1±0.10	≤ 0.01	0.04±0.01	≤ 0.01	1.4±0.05
RL 5705	Cladina alpestris	GCH-1-1	Gunnar Central	7.03±0.3	0.08±0.01	≤ 0.01	0.02±0.01	≤ 0.01	0.48±0.05
RL 5706	Cladonia amourocraea	GCH-2-2	Gunnar Central	14.4±0.2	0.07±0.01	≤ 0.01	0.02±0.01	0.02±0.01	0.30±0.05
RT 5707	Picea mariana	GMV-SPRU-1A	Gunnar Main	0.69±0.06	1.4±0.1	≤ 0.01	0.03±0.01	0.02±0.01	0.22±0.05
RT 5708	Salix interior	LBV-WIL-2A	Langley Bay	0.16±0.07	0.08±0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.2
RT 5709	S. interior (root)	GMV-WIL-1B	Gunnar Main	562±3	0.42±0.03	≤ 0.01	0.12±0.01	0.08±0.02	1.0±0.05
RT 5710	Pinus banksiana	GMT-6-JP (2)	Gunnar Main	2.84±0.1	0.19±0.02	≤ 0.01	0.05±0.01	≤ 0.01	0.45±0.05

TABLE 7.2.3: RADIONUCLIDES IN VEGETATION FROM GUNNAR TAILINGS AND VICINITY, 1985 (this study)

Monenco No.	Plant Species	Sample Identification	General Location	U-238 (ppm)	Cross-Check U-238 (ppm)	Ra-226 (Bq/g)	Th-232 (Bq/g)	Th-230 (Bq/g)	Th-228 (Bq/g)	Pb-210 (Bq/g)
RV 5885	Picea mariana	G-1	Control 2	≤ 0.2	0.08	0.03±0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.33±0.55
RV 5886	Salix sp.	G-2	Control 2	≤ 0.2		≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.32±0.05
RV 5887	Calamagrostis canadensis	G-4	Control 2	≤ 0.2		0.02±0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.34±0.05
RV 5889	Cladonia sp.	G-6	Control 1	0.8		0.09±0.01	≤ 0.01	0.03±0.01	0.02±0.01	0.88±0.05
RV 5890	Picea mariana	G-7	Control 1	≤ 0.2		0.14±0.01	≤ 0.01	≤ 0.01	< 0.01	0.31±0.05
RV 5891	Salix sp.	G-8	Control 1	≤ 0.2		≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.37±0.05
RV 5892	Typha latifolia	G-9	Zemel Creek Mouth	0.6		0.06±0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.48±0.05
RV 5893	Typha latifolia	G-10	Flooded Pit	1.4	1.1±0.2	0.14±0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.30±0.05
RV 5894	Calamagrostis canadensis	G-11	Flooded Pit	≤ 0.2		0.11±0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.24±0.05
RV 5895	Salix sp.	G-12	Frog Pond	≤ 0.2		0.06±0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.74±0.05
RV 5896	Calamagrostis canadensis	G-13	Frog Pond	≤ 0.2		0.11±0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.27±0.05
RV 5897	Carex aquatilis	G-14	Frog Pond	1.2		0.12±0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.30±0.05
RV 5898	Typha latifolia	G-15	Gunnar Central	0.4		0.05±0.01	≤ 0.01	0.02±0.01	≤ 0.01	0.20±0.05
RV 5899	Hordeum jubatum	G-16	Gunnar Central	0.4		0.14±0.01	≤ 0.01	0.03±0.01	≤ 0.01	0.34±0.05
RV 5900	Typha latifolia	G-28	Langley Bay	≤ 0.2	0.24±0.16	0.06±0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.2
RV 5901	Carex aquatilis	G-30	Langley Bay	≤ 0.2		0.45±0.03	≤ 0.01	≤ 0.01	0.02±0.01	0.50±0.05
RV 5902	Salix sp.	G-33	Langley Bay	0.4		0.09±0.01	≤ 0.01	0.02±0.01	≤ 0.01	0.62±0.05
RV 5903	Hordeum jubatum	G-35	Gunnar Main	3.0	3.03±0.2*	0.37±0.02	≤ 0.01	0.09±0.01	0.02±0.01	0.45±0.05
RV 5904	Salix sp.	G-39	Gunnar Main	0.4		0.05±0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.43±0.05

* Repeat cross-check analysis of RV 5903 gave 3.07±0.1 ppm U-238.

TABLE 7.2.4: TRACE METALS IN VEGETATION FROM GUNNAR TAILINGS AND VICINITY, 1983 (M. Apps, Northern Forest Research Station)

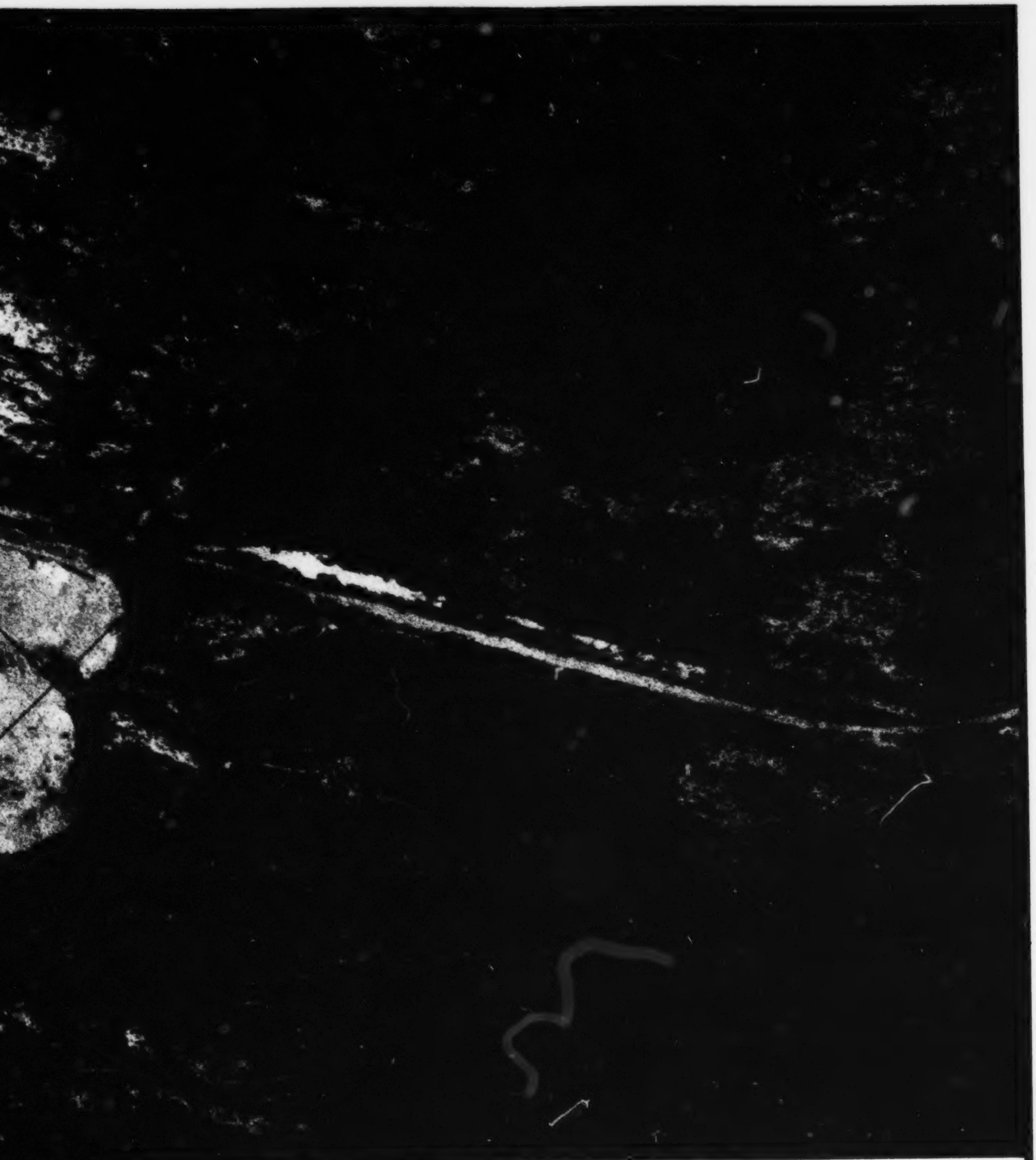
Monenco No.	RV5693	RV5694	RV5695	RV5696	RV5697	RV5698	RV5699	RV5700	RV5701	RV5706
Sample Identification	GMV-BAR-1A	GMV-SALT-1A	GMV-TYPH-2A	GMV-WIL-1A	GMV-CAR-2A	GCV-PUC-1A	GCV-CAR-2A	LBV-WIL-1A	LBV-WIL-1A	GCH-2-2
Plant Species	Hordeum jubatum	Pucinellia nutalliana	Typha latifolia	Salix sp.	Carex aquatilis	Pucinella nutalliana	Carex aquatilis	Pucinellia nutalliana	Salix sp.	Cladonia amourocraea
General Location	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Main	Gunnar Central	Gunnar Central	Langley Bay	Langley Bay	Gunnar Central
Aluminum	1000	58	113	45	360	121	58/64	176	37	142
Arsenic	2.2	0.6	0.3	0.7	1.0	0.3	0.2/0.2	0.5	L 0.1	0.3
Barium	2.0	2.0	1.0	1.0	5.0	2.5	2.5/2.0	3.0	L 0.5	0.5
Beryllium	0.4	L 0.1	L 0.1	L 0.1	0.3	L 0.1	L 0.1/0.1	L 0.1	L 0.1	L 0.1
Cadmium	0.3	L 0.5	L 0.5	0.5	0.2	0.2	0.4/0.2	0.2	1.2	0.1
Calcium	2800	1150	2500	5200	2900	3400	1990/2400	930	4900	320
Chromium	3.8	0.4	0.4	0.4	2.0	1.4	2.0/1.2	3.0	0.2	0.6
Cobalt	2.0	0.5	0.5	L 0.5	1.5	1.0	1.5/1.0	1.5	1.0	L 0.5
Copper	14.2	5.2	3.2	10.0	7.6	4.6	10.2/13.0	10.0	8.8	0.6
Iron	2020	114	48	96	590	220	144/173	370	43	133
Lead	32	6.0	2.0	3.5	14.5	12.5	10.0/7.5	20	3.5	2.0
Magnesium	2200	1960	8900	1610	3600	3000	2800/3200	1330	4100	196
Manganese	49	57	1720	84	880	141	750/890	91	310	19
Molybdenum	L 0.3	L 0.3	L 0.3	L 0.3	L 0.3	L 0.3	L 0.3/0.3	L 0.3	L 0.3	L 0.3
Nickel	16.0	2.0	0.5	3.0	3.0	3.0	5.5/7.5	7.5	1.5	L 0.5
Potassium	9700	2900	12400	10600	15300	2000	5600	3000	11600	780
Selenium	1.6	1.0	2.2	1.4	5.0	0.3	4.8/4.5	1.2	0.9	0.2
Silver	L 0.5	10.0	L 0.5	L 0.5	3.0	L 0.5	4.0/2.0	8.0	L 0.5	1.0
Sodium	100	139	330	62	174	240	182/193	71	64	24
Strontium	8.0	4.5	12.5	16.0	14.0	14.0	17.0/20.0	5.0	14	1.0
Vanadium	4.0	1.0	1.6	2.0	1.4	2.0	1.6/1.5	1.4	1.8	0.8
Zinc	15.0	6.2	3.2	154	23	6.0	20/26	13.6	97	8.6

Concentrations expressed as ug/g dry weight.

TABLE 7.2.5: TRACE METALS IN VEGETATION FROM GUNNAR TAILINGS AND VICINITY, 1985 (this study)

Monenco No.	RV5889	RV5899	RV5895	RV5897	RV5901	RV5902
Sample Identification	G-6	G-16	G-12	G-14	G-30	G-33
Plant Species	*Cladonia* sp.	*Hordeum jubatum*	*Salix* sp.	*Carex aquatilis*	*Carex aquatilis*	*Salix* sp.
General Location	Control 1	Gunnar Central	Frog Pond	Frog Pond	Langley Bay	Langley Bay
Aluminum	41/56	920	64	9.5/13.0	14.5/10.5	68/55
Arsenic	L 0.1/0.1	0.5/0.7	0.1	0.2/0.2	L 0.1/0.1	0.3/0.3
Barium	1.5/0.5	L 0.5	L 0.5	L 0.5/0.5	2.5/1.0	1.5/1.0
Beryllium	L 0.1/0.1	L 0.1	L 0.1	L 0.1/0.1	L 0.1/0.1	L 0.1/0.1
Cadmium	6.9/8.2	12.1	4.7	2.2/2.4	1.3/1.5	14.7/16.0
Calcium	1020/1150	1890	1260	990/1240	2000	17100/13800
Chromium	8.4/7.2	9.2	L 0.2	1.0/1.4	1.6/1.0	3.5/4.0
Cobalt	L 0.5/0.5	1.0	L 0.5	L 0.5/1.0	1.0/1.0	5.0/5.5
Copper	6.0/4.8	2.4	7.2	4.8/5.8	6.4/4.2	9.4/9.4
Iron	129/122	820	33	42/54	43/31	139/118
Lead	3.5/2.5	7.5	0.5	3.5/7.0	9.0/7.0	16.5/17
Magnesium	1090/1220	520	2110	1490/1760	1660/1020	2900/2200
Manganese	150/130	80	68	196/240	310/290	1880/2000
Molybdenum	L 0.3/0.3	L 0.3	L 0.3	L 0.3/0.3	L 0.3/0.3	L 0.3/0.3
Nickel	4.0/3.0	4.0	0.5	L 0.5/0.5	1.5/1.0	3.5/4.0
Potassium	10200/11100	1070	940	11000/13400	11600	9800/10700
Selenium	2.0/2.0	L 0.1	3.0	1.0/0.8	1.2/1.0	1.1/1.2
Silver	4.5/2.5	L 0.5	1.5	14.5/2.5	11.5/14.5	L 5.0/5.5
Sodium	31/26	6	L 2	80/96	9	22/16
Strontium	6.5/7.5	10.0	24	5.5/6.5	9.5/6.0	26/30
Vanadium	0.4/0.4	2.0	2.8	0.2/0.4	0.3/1.8	0.7/1.1
Zinc	17.0/18.0	20	102	16.2/22	19.3/20	390/370

Concentrations expressed as ug/g dry weight.



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SCALE	DRAWN BY PMG	FIG. 7.2.2
DATE 29·01·86	APPROVED BY	

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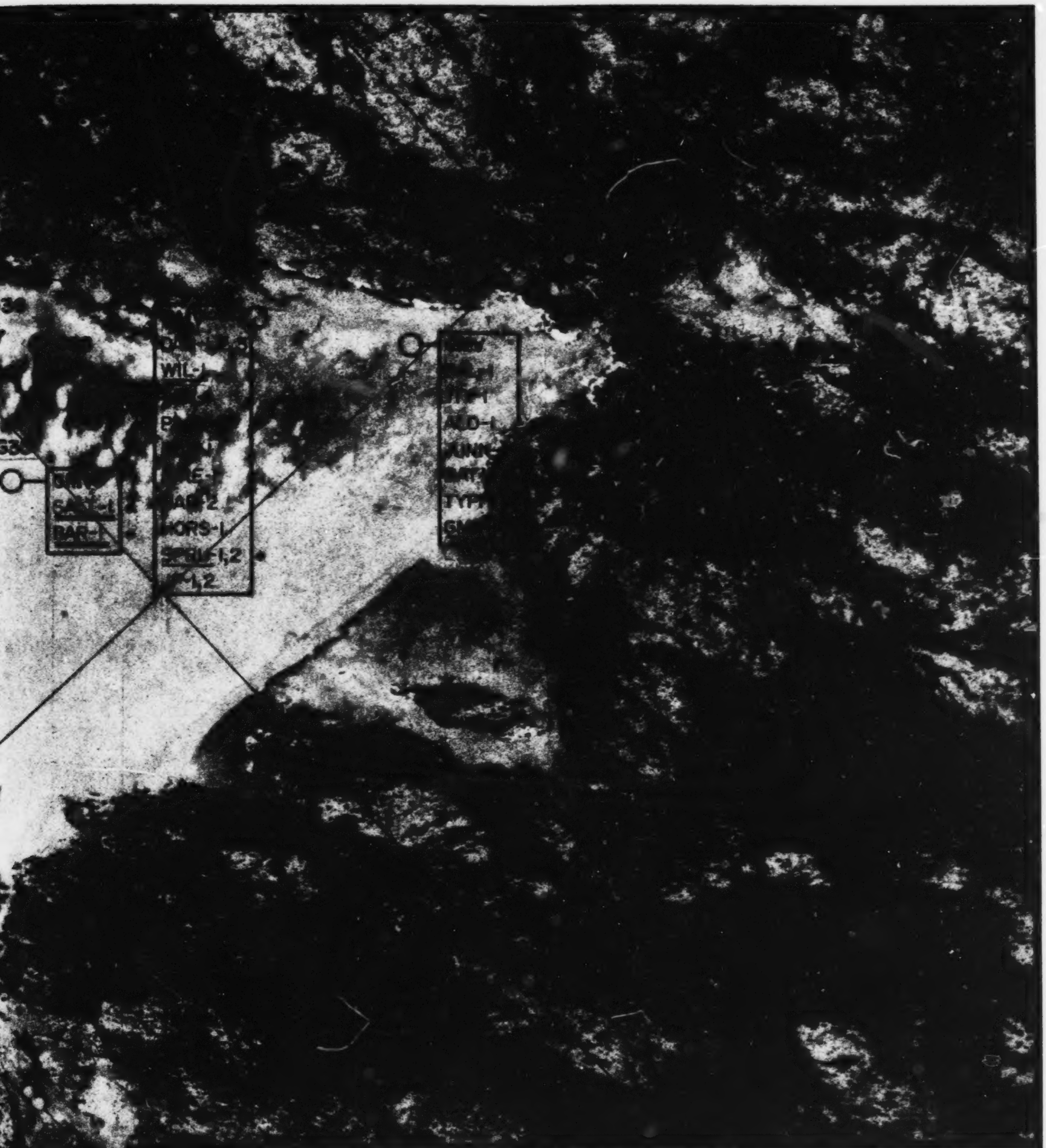
CAR-1
YPH-3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BAR-1
SPRU-1,2
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ALD-1
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SCALE	DRAWN BY PMG	FIG. 7.2.2
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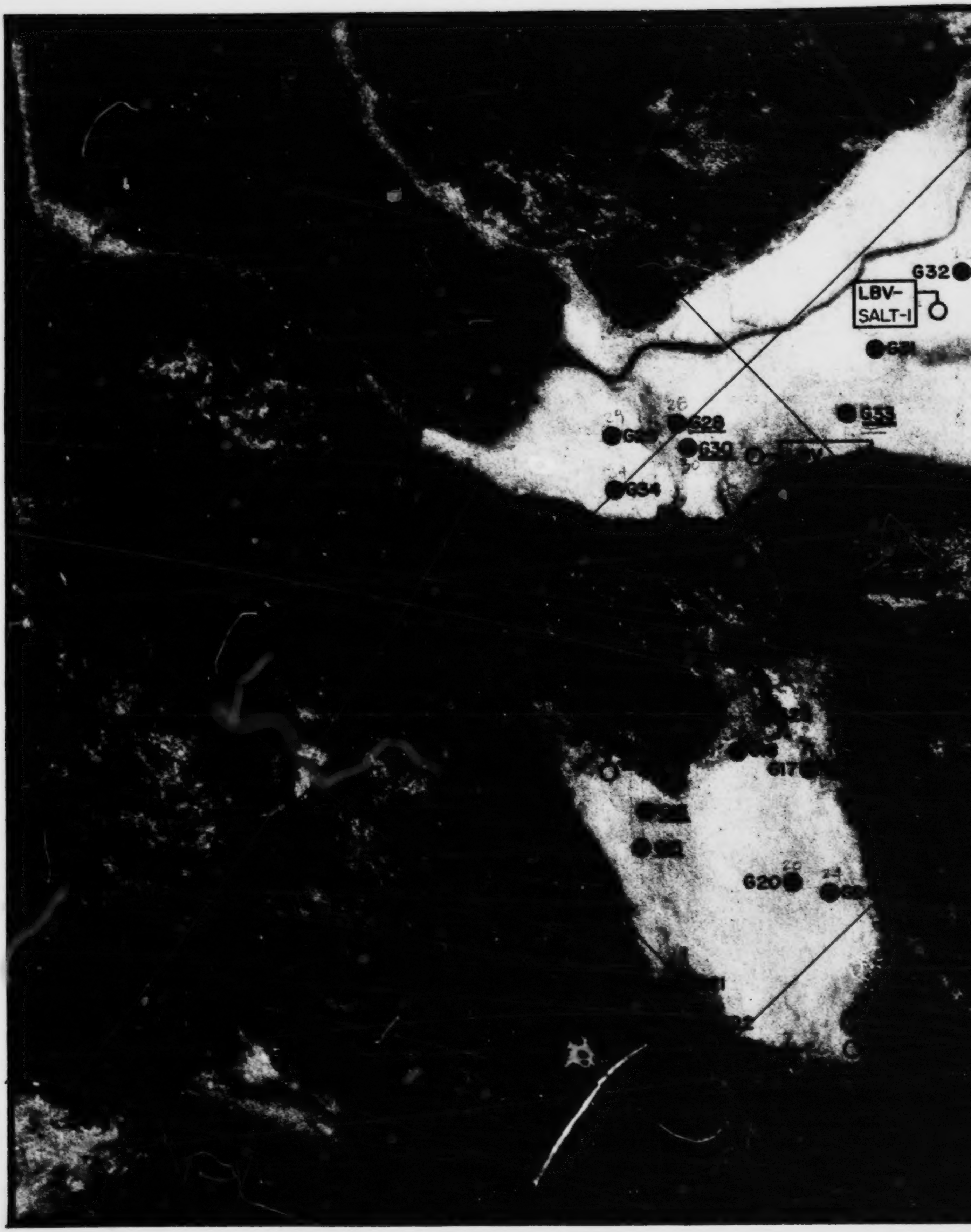
G32
LBV-
SALT-I
G31
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24

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FIG. 7.2.2

TABLE 7.2.6: SPECIES REPRESENTED BY ARCHIVED VEGETATION SAMPLES NOT ANALYZED IN 1985

Species	Northern Forest Research Station Samples 1983	BEAK Samples 1985
Typha latifolia	GMV-TYPH-1, 3	G37
Carex aquatilis	GMV-CAR-1	G18, G23, G38
Juncus balticus	GMV-JUNK-1, 2	-
Picea mariana	GMV-SPRU-2, 3	G40
Taraxacum officinale	GMV-DAN-1, 2, 3	-
Achillea millefolium	GMV-YAR-1	-
Plantago major	GMV-PLAN-1	-
Shepherdia canadensis	GMV-BUF-1	-
Epilobium angustifolium	GMV-FIRE-1	-
Equisetum arvense	GMV-HORS-1, EQU-1	-
Hordeum jubatum	GMV-BAR-2	-
Deschampsia caespitosa	LBV-GRAS-2	G20, G29, G32
Pinus banksiana	GMV-JP-1, 2	-
Calamagrostis inexpansa	GMV-CAL-1; GCV-CAL-1	G24, G27
Calamagrostis canadensis	-	G25, G26
Puccinellia nutalliana	LBV-SALT-1	G31, G34
Triglochin palustris	GMV-TRI-1	-
Alnus crispa	GMV-ALD-1; LBV-ALD-1, 2	-
Aster laurentianus	GMV-RAY-1	G22
Betula papyrifera	LBV-BIR-1, 2, 3	G17
Cladonia amourocraea	-	G3
Vallisneria sp.	-	G5

Sample locations shown on Figure 7.2.2.

in Figure 7.2.2 include both analyzed and archived samples. A complete list of species represented by archived samples is given in Table 7.2.6.

7.3 SOILS

7.3.1 Field Procedures

Thirteen surficial soil samples were collected from the root zones of dominant plant species in each vegetation community during the 1985 field season at Gunnar. The communities sampled, the sample codes, and the dominant plant species for each tailings area are listed in Table 7.3.1. Specific sampling locations are shown on Map 7.3.1.

Samples of approximately 200 g were collected at depths of 15 to 20 cm below the surface. Soil was removed with a stainless steel spoon, placed in a Whirl-pac bag, sealed and transported to the laboratory within four days. Samples were held at 4°C in the laboratory prior to analysis.

7.3.2 Laboratory Procedures

Five soil samples were analyzed for uranium and thorium series radionuclides by MONENCO Analytical Laboratories (U-238, Ra-226, Th-232, Th-228 and Pb-210). Uranium-238 measurements reported by MONENCO were performed by delayed neutron activation at Atomic Energy of Canada Ltd. Bulk soil samples were dessicated prior to analysis.

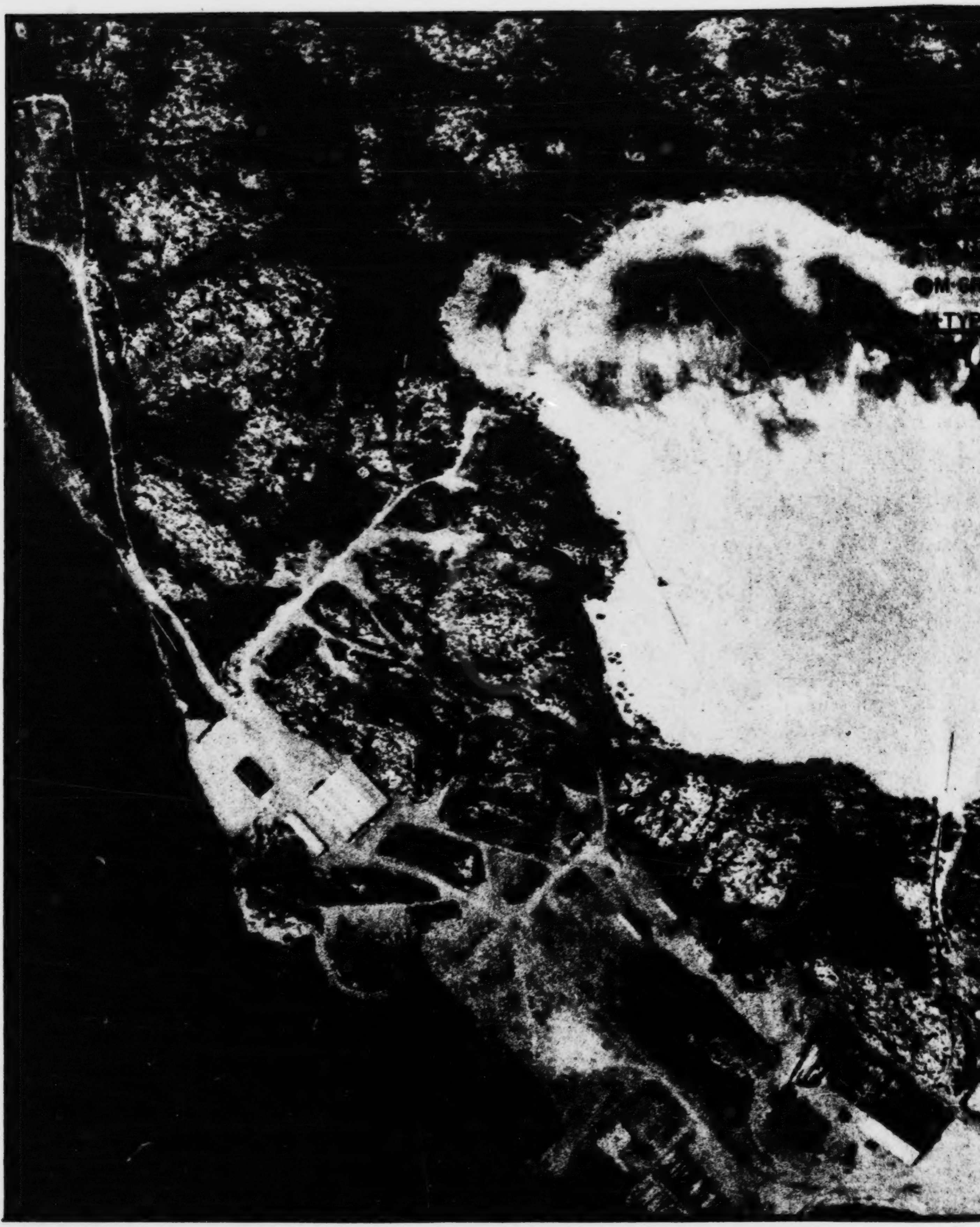
Methods for other radionuclides follow Chiu and Dean (1984). Ra-226 and thorium isotopes were determined by high resolution alpha spectrometry following pyrosulphate fusion. Lead-210 was determined indirectly by measurement of Bi-210 using a beta-counter, following pyrosulphate fusion.

Trace metals were determined by decoupled plasma emission scan (Spectrometrics, Inc., undated) of aqua regia extracts (MOE, 1983).

TABLE 7.3.1: ROOT ZONE SOIL SAMPLES COLLECTED FROM GUNNAR TAILINGS AREAS AND ASSOCIATED DOMINANT PLANT SPECIES

Sample Code	General Location	Vegetation Community	Plant Species
M-FLAT*	Gunnar Main	Mud Flat	Juncus sp.
M-TYPHA*		Cattail	Typha latifolia
M-GRASS		Grass	Hordeum jubatum
M-SHRUB		Shrub	Alnus sp., Salix sp., Betula sp.
C-GRASS*	Gunnar Central	Grass	Calamagrostis inexpansa
C-SEDGE		Sedge	Caryx aquatilis
C-GRASS/SEDGE		Grass/Sedge	C. inexpansa, C. aquatilis
C-ALDER		Shrub	Alnus sp., Salix sp., Betula sp.
F-CARYX*	Frog Pond	Sedge	Caryx aquatilis
F-ALDER		Shrub	Alnus sp., Salix sp., Betula sp.
L-GRASS	Langley Bay	Grass	Deschampsia sp.
L-SEDGE*		Sedge	Caryx aquatilis
L-ALDER		Shrub	Alnus sp., Salix sp., Betula sp.

* Indicates samples analyzed for radionuclides and trace metals.


●M-GR
M-TYP

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SCALE	DRAWN BY PMG	FIG. 7.3.1
DATE 28·01·86	APPROVED BY	

7.3.3 QA/QC Program

MONENCO's internal quality assurance program includes one replicate analysis per batch of 15 to 20 samples, one or two standards per batch, and one certified reference sample (EPA, NBS or CANMET) per batch. In addition, a tracer is added to every sample to check recovery. Barium-133 and Th-234 are used for determination of Ra-226 and thorium isotopes.

MONENCO participates successfully in analysis check programs initiated by Environment Canada, CANMET, CCRMP, U.S. EPA Las Vegas and the Analytical Subcommittee of the Canadian Uranium Producers Metalurgical Committee.

Internal quality assurance associated with trace metal analyses by BEAK includes routine use of certified and standard reference materials (EPA, NBS, NRC), replicate analyses, and spiked samples to eliminate interferences and confirm recovery. Successful participation in interlaboratory studies involving metal determinations in sediments includes studies sponsored by Environment Canada, Environmental Protection Service, and Fisheries and Oceans Canada.

7.3.4 Data Presentation

Radionuclide determinations in surficial soil samples associated with tailings vegetation are listed in Table 7.3.2, with counting errors for each determination and approximate detection limits. All determinations exceeded detection limits for soils.

The root zone soil samples analyzed represent different vegetation communities and, therefore, may not be comparable. They suggest, however, that the highest uranium-238 concentrations occur on Gunnar Main, while other radionuclides reach peak concentrations in the Frog Pond or Langley Bay tailings.

Trace metal determinations in surficial soil samples associated with tailings vegetation are listed in Table 7.3.3, with approximate detection limits. Soil moisture and grain size analyses are included.

TABLE 7.3.2: RADIONUCLIDES IN ROOT ZONE SOILS FROM GUNNAR TAILINGS AREAS, 1985 (this study)

Monenco No.	Sample Identification	General Location	Dominant Plant	U-238 (ppm)	Ra-226 (Bq/g)	Th-232 (Bq/g)	Th-230 (Bq/g)	Th-228 (Bq/g)	Pb-210 (Bq/g)
RS 5908	F - Carex	Frog Pond	Carex aquatilis	64.4	34.0±1.0	0.22±0.06	14.0±0.5	0.74±0.10	10.0±0.2
RS 5909	L - Sedge	Langley Bay	Carex aquatilis	50.2	14.0±0.6	0.22±0.06	6.4±0.3	0.25±0.06	11.8±0.2
RS 5910	C - Grass	Gunnar Central	Calamagrostis inexpansa	41.1	4.6±0.2	0.04±0.03	3.2±0.1	0.30±0.08	5.8±0.2
RS 5911	M - Flat	Gunnar Main	Juncus sp.	95.8	7.9±0.4	0.10±0.04	5.6±0.4	0.32±0.08	7.2±0.2
RS 5912	M - Typha	Gunnar Main	Typha latifolia	83.5	9.9±0.4	0.16±0.05	10.7±0.4	0.26±0.06	8.8±0.2

Specific sample locations are shown on Figure 7.3.1.

TABLE 7.3.3: TRACE METALS IN ROOT ZONE SOILS FROM GUNNAR TAILINGS AREA 1985 (this study)

Monenco No.	RS5908	RS5909	RS5912
Sample Identification	F-Carex	L-Sedge	M-Typha
Plant Species	*Carex* aquatilis	*Carex* aquatilis	*Typha* latifolia
General Location	Frog Pond	Langley Bay	Gunnar Main
Aluminum	15900	11300	10000/9800
Arsenic	47	33	21/18
Barium	63	152	125/136
Beryllium	3.3	2.4	2.6/2.4
Cadmium	6.5	5.0	4/2
Calcium	40000	17700	13300/13100
Chromium	31	23	22/19
Cobalt	10	7	7/4
Copper	44	22	32/22
Iron	23000	18000	15400/17400
Lead	290	162	160/145
Magnesium	24000	18800	15000/14100
Manganese	210	178	250/260
Molybdenum	12.3	8.3	8.1/6.9
Nickel	9	8	8/8
Potassium	1530	1000	890/860
Selenium	0.9	0.7	0.5/0.2
Silver	4	2	3/2
Sodium	1470	910	710/770
Strontium	66	29	20/20
Vanadium	34	26	22/21
Zinc	60	35	28/27
Particle Size*(FAST)%	54.6	29.1	11.5

* Particle Size = % less than 90 um.

Bioaccumulation factors can be computed for the sedge Carex aquatilis in the Frog Pond and in Langley Bay, based on analysis of soil and vegetation samples from the 1985 survey, and for the cattail Typha latifolia on Gunnar Main, based on analysis of 1985 soil samples and 1983 vegetation samples. These bioaccumulation factors are listed in Table 7.3.4.

TABLE 7.3.4: BIOACCUMULATION FACTORS FOR RADIONUCLIDES AND TRACE METALS IN GUNNAR TAILINGS VEGETATION

	Bioaccumulation Factor[1]		
Analytical Parameter	Typha latifolia[2] Gunnar Main	Carex aquatilis[3] Frog Pond	Carex aquatilis[3] Langley Bay
U-238	0.0168	0.0186	L 0.0040
Ra-226	0.0101	0.0035	0.0321
Th-232	L 0.0625	L 0.0455	L 0.0455
Th-230	0.0019	L 0.0007	L 0.0016
Th-228	0.1154	L 0.0135	0.0800
Pb-210	0.0352	0.0300	0.0424
Metals			
Aluminum	0.0114	0.0007	0.0011
Arsenic	0.0154	0.0043	L 0.0030
Barium	0.0071	0.0079	0.0115
Beryllium	L 0.0400	L 0.0300	L 0.0417
Cadmium	0.1667	0.3598	0.4667
Calcium	0.1894	0.0279	0.1130
Chromium	0.0195	0.0387	0.0565
Cobalt	0.0909	L 0.0300	0.1429
Copper	0.1185	0.1205	0.2409
Iron	0.0015	0.0209	0.0021
Lead	0.0131	0.0183	0.0494
Magnesium	0.6117	0.0677	0.0921
Manganese	6.745	1.038	1.685
Molybdenum	L 0.0400	L 0.0244	L 0.0361
Nickel	0.0625	L 0.0556	0.1563
Potassium	13.41	7.974	11.26
Selenium	6.286	1.000	1.571
Silver	L 0.2500	2.1250	6.500
Sodium	0.4459	0.0599	0.0256
Strontium	0.6250	0.0909	0.2672
Vanadium	0.0773	0.0088	0.0423
Zinc	0.1143	0.3183	0.5629

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[1] Dry weight concentration or activity ratio of above-ground plant material and associated root zone soils.

[2] Plant data from M. Apps, Northern Forest Research Centre, 1983; soil data from this study, 1985.

[3] Plant and soil data from this study, 1985.

7.4 TERRESTRIAL WILDLIFE

7.4.1 Caribou

The Beverly Herd is the major caribou herd which historically has used the Athabasca Lake area during the migration period. Figure 7.4.1 illustrates the winter distribution of the herd over the past 28 years. Generally, the herd does not migrate so far south as it did in the 1950's and 1960's (Jakinchuk et al., 1983). The winter of 1979-80, however, was an exception. The herd penetrated south moving close to the north shores of Lake Athabasca. Any past caribou sightings on the Crackingstone Peninsula would have probably occurred during the 1979-80 winter season.

7.4.2 Moose

Mr. Ed. Kowal (Wildlife Ecologist, Prince Albert) indicates that the region has low moose densities and estimates that there are less than 0.3 moose/km^2 (0.5 moose/mile^2) in general (pers. comm., March 1985). Burnover areas and drainage basins represent prime habitat for moose. Field signs indicate that moose frequent the Gunnar tailings. The birch (Betula) and willow (Salix) shrubs which are now colonizing the edge of the tailings piles are preferred browse species. Horsetail (Equisetum), found on Gunnar Main and in the Frog Pond, and pondweeds (Potomogeton) found in Langley Bay, are eaten by moose in the summer. Photographic Plate 7.8.9 shows a dense growth of horsetail on Gunnar Main. Thus, the potential exists for bioaccumulation of radionuclides by moose.

7.4.3 Small Game

Rabbits, squirrels, grouse and ptarimigan are common in the Uranium City and Gunnar areas. Due to their ubiquitous distribution and abundance, most hunting probably occurs near human population centres. Both spruce grouse and ruffed grouse are present.

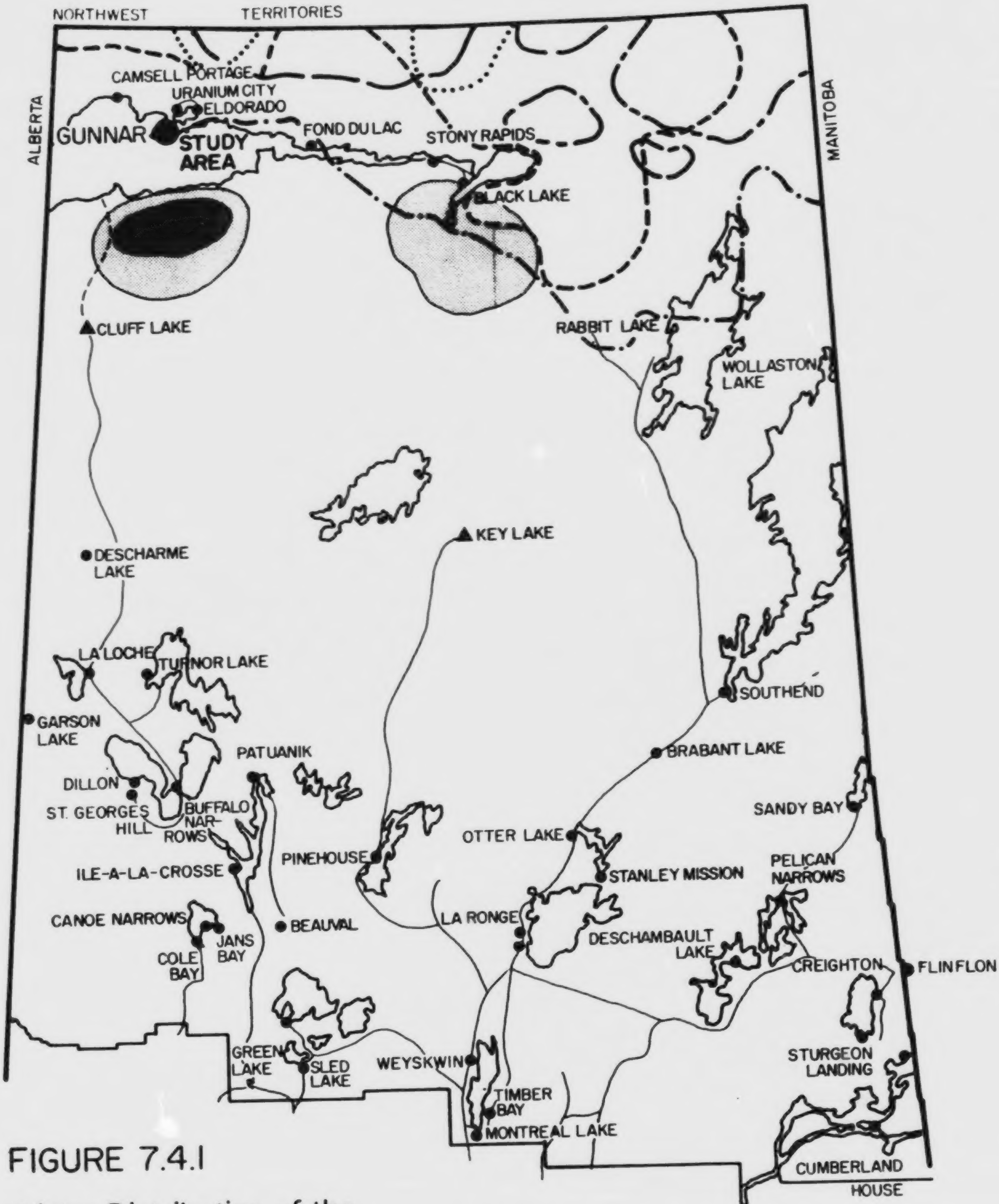

NORTHWEST TERRITORIES
ALBERTA
MANITOBA
CAMSELL PORTAGE
URANIUM CITY
ELDORADO
GUNNAR
STUDY AREA
FOND DU LAC
STONY RAPIDS
BLACK LAKE
CLUFF LAKE
RABBIT LAKE
WOLLASTON LAKE
KEY LAKE
DESCHARME LAKE
LA LOCHE
TURNOR LAKE
GARSON LAKE
SOUTHEND
BRABANT LAKE
PATUANIK
DILLON
ST. GEORGES HILL
BUFFALO NARROWS
SANDY BAY
OTTER LAKE
PINEHOUSE
ILE-A-LA-CROSSE
STANLEY MISSION
PELICAN NARROWS
CANOE NARROWS
BEAUVAL
LA RONGE
JANS BAY
COLE BAY
DESCHAMBAULT LAKE
CREIGHTON
FLIN FLON
GREEN LAKE
SLED LAKE
WEYSKWIN
STURGEON LANDING
TIMBER BAY
MONTREAL LAKE
CUMBERLAND HOUSE
LEGEND
▨ 1957/58 WINTERING GROUNDS
■ 1959/60 WINTERING GROUNDS
1966/67
1978/79
1979/80
1981/82
1982/83

FIGURE 7.4.1

Winter Distribution of the Beverly Caribou Herd in the Study Area (Modified from Kelsall, 1960; Thomas, 1969; Saskatchewan Wildlife Branch, 1983)

7.4.4 Fur Bearers

Coyote, fishes, red fox, lynx, marten, beaver, mink, muskrat, otter, squirrels and weasel are trapped in the Uranium City area. Beaver have dammed the drainage channel between Gunnar Main and Gunnar Central to create the Frog Pond. Photographic Plate 7.8.10 shows the beaver dam. One Uranium City resident, Delbert Augier, uses the Crackingstone Peninsula for trapping. According to Mr. G. Bihun, the Uranium City Conservation Officer, Mr. Augier's trapline passes through the Gunnar site. The 1984 production and cash value figures for Mr. Augier's trapline are presented in Table 7.4.1. With the exception of squirrels, these animals are trapped solely for fur as opposed to meat.

TABLE 7.4.1: 1983-84 PRODUCTION AND CASH VALUE FIGURES FOR TRAPLINE RUNNING THROUGH THE GUNNAR SITE

Name of Trapper	Beaver	Coyote	Fisher	Red Fox	Lynx	Marten	Mink	Muskrat	Otter	Squirrel	Weasel	Total
Delbert Augier	-	1	-	5	2	1	2	-	1	-	1	13
		$50.00		$198.00	$600.00	$60.00	$20.00		$40.00		$1.00	$969.00

Source: Wildlife Branch, Fur Division, Department of Parks and Renewable Resources. 1983-84. Individual Trappers Harvest.

7.5 AQUATIC ECOLOGY

The aquatic biota in the vicinity of the Gunnar site have been comprehensively studied by EPS, Regina (D. Waite, pers. comm.) and the Saskatchewan Research Council (Tones, 1982). The EPS analyses have not yet been completed, but data will soon be available from CCIW. The SRC data have been reported and are tabulated in Volume 7.6. Methods associated with the EPS study are described below.

7.5.1 EPS Field Procedures

In July 1983, five sampling sites were established in the Gunnar area (Figure 7.5.1). Water, sediment, aquatic macrophyte, game and forage fish and plankton were collected for radionuclide and trace metal analysis. The water, sediment and plankton samples collected at each station are listed in Table 7.5.1. Forage fish were also collected from the Sampson Island control site (Station 1) for radionuclide flux and uptake experiments in Langley Bay.

7.5.1.1 Water Samples

Depth-integrated samples were collected on three consecutive days at each sampling station using a five-litre vertical non-metallic Van Dorn bottle. At Stations 1 and 2, only total samples were collected. At the remaining stations, samples were collected for total and dissolved radionuclides and metals, and total routine chemistry. The samples for the dissolved parameters were filtered through a 0.45 um filter and preserved at the end of each day. The total samples were preserved at the same time.

Conductivity and temperature were measured at the time of sample collection using a Yellow Springs Instrument Direct Reading Salinity Conductivity Temperature meter. Field pH measurements were made using a Sargent Welch portable pH meter. Dissolved oxygen measurements were done using a Hach kit employing the azide modification of the Winkler method. Samples for dissolved oxygen were fixed and titrated immediately after collection.

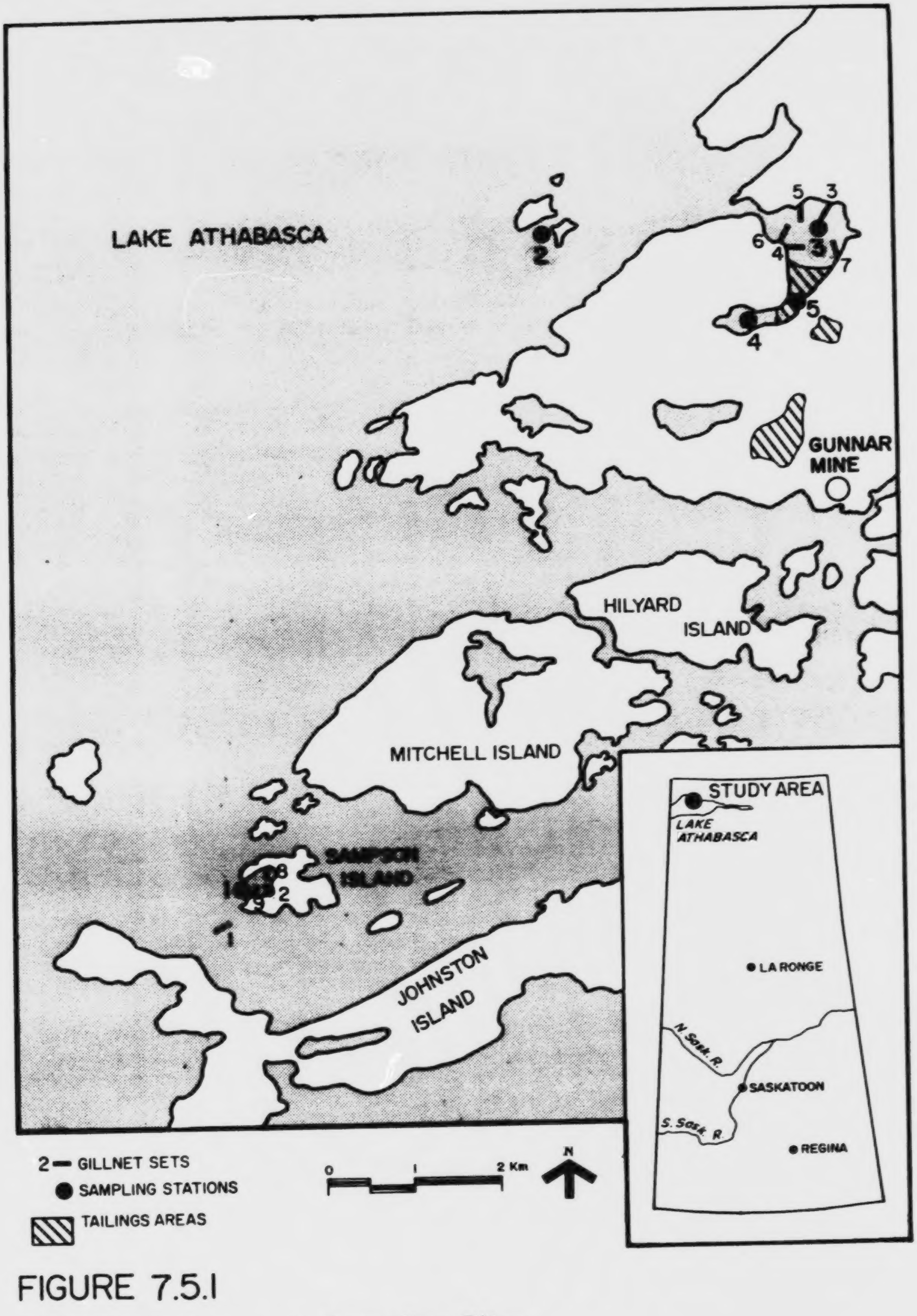

LAKE ATHABASCA
2
5
3
6
4
3
7
5
4
GUNNAR MINE
HILYARD ISLAND
MITCHELL ISLAND
SAMPSON ISLAND
8
1
2
9
1
JOHNSTON ISLAND
STUDY AREA
LAKE ATHABASCA
LA RONGE
N. Sask. R.
SASKATOON
S. Sask. R.
REGINA
2 — GILLNET SETS
● SAMPLING STATIONS
▨ TAILINGS AREAS
0
1
2 Km
N

FIGURE 7.5.1
EPS Study Area and Sampling Sites.

TABLE 7.5.1: WATER, SEDIMENT AND PLANKTON SAMPLES COLLECTED FOR EPS STUDY

Station No.	Dates 1983	Samples Collected
1	27, 28, 29 July	water for routine chemistry water for total metals water for total radionuclides
	27 July	sediments for metals sediments for radionuclides net plankton nanoplankton
2	27, 28, 29 July	water for routine chemistry water for total metals water for total radionuclides
	27 July	sediment for metals sediment for radionuclides net plankton nanoplankton
3	27, 28, 29 July	water for routine chemistry water for total metals water for total radionuclides water for dissolved metals water for dissolved radionuclides
	27 July	sediment for metals sediment for radionuclides net plankton nanoplankton
	29 July	surface water for total radionuclides surface water for total metals bottom water for total radionuclides bottom water for total metals
4	27, 28, 29 July	water for routine chemistry water for total metals water for total radionuclides water for dissolved metals water for dissolved radionuclides
	27 July	sediment for metals sediment for radionuclides net plankton nanoplankton

TABLE 7.5.1: WATER, SEDIMENT AND PLANKTON SAMPLES COLLECTED FOR EPS STUDY

Station No.	Dates 1983	Samples Collected
5	27, 28, 29 July	water for routine chemistry water for total metals water for total radionuclides water for dissolved metals water for dissolved radionuclides nanoplankton

Routine Chemistry:	pH, total alkalinity, bicarbonate, carbonate, sulphate, conductance, chloride, total hardness, calcium hardness, total carbon, inorganic carbon, total phosphate.
Metals:	As, Cr, Co, Cu, Pb, Ni, Zn, Mn, Cn, Mg, K, Na, Fe.
Radionuclides:	Pb-210, Ra-226, Th-228, Po-210, U-nat.

TABLE 7.5.2: AQUATIC MACROPHYTES COLLECTED FOR ANALYSIS

Control Potamogeton	for radionuclides only
Control Myriophyllum	for radionuclides and metals
Langley Bay Cattail Stems	for radionuclides and metals
Langley Bay Cattail Roots	for radionuclides and metals
Langley Bay Myriophyllum	for radionuclides and metals
Langley Bay Potamogeton	for radionuclides and metals

7.5.1.2 Sediment Samples

Sediment samples were collected at Stations 1 through 4 using a 6" x 6" Ekman grab sampler. The samples were split to provide a sample for each laboratory and placed in Whirl pac bags. The sediment samples were packed in coolers and shipped to the respective laboratories for analysis.

7.5.1.3 Aquatic Macrophytes

Grab samples were collected from Sampson Island, Langley Bay and Langley Back Bay as outlined in Table 7.5.2. Approximately 1 kg wet weight of each sample was taken at each site for each laboratory. The samples were placed into plastic bags and packed in coolers.

Samples were also collected for identification in each area as outlined in Table 7.5.3. These samples were preserved with 10% formalin.

7.5.1.4 Fish

Fish were collected using a gillnet on the dates and locations shown on Figure 7.5.1 and in Table 7.5.4. The gillnets were in 45.7 m lengths which were joined together to obtain the required lengths that are shown in Table 7.5.4. All the gillnets had 7.9 cm mesh. The total fish caught in each net set is shown in Table 7.5.5.

The fish used for analysis were weighed and sexed and fork length was determined. These measurements are shown in Table 7.5.6. Then, the fish were dissected and the organs shown in Table 7.5.7 removed. These organs were combined by species until a maximum of 500 grams were obtained. All tissue samples were kept on dry ice until shipment.

TABLE 7.5.3: SAMPLES OF AQUATIC BIOTA FOR IDENTIFICATION

1. Littoral Macrophytes	
a) Langley Back Bay	24 July 1983
b) Langley Back Bay	undated
2. Littoral Macroinvertebrate	
a) Langley Back Bay	24 July 1983
b) Langley Bay	24 July 1983
c) Lake Athabasca Control	undated
3. Forage Fish	
a) Langley Bay	undated
b) Bay off Sampson Island	20 July 1983
c) Sampson Island	24 July 1983

TABLE 7.5.4: GILL NET SETS - EPS STUDY

Set No.	Date of Set	Date Lifted	Length (yd)	Location
1	21 July 1600	22 July 1100	50	Control
2	22 July 1130	23 July 1100	100	Control
3	23 July 1300	24 July 1000	50	Langley Bay
4	25 July 1700	26 July 1000	200	Langley Bay
5	29 July 1800	30 July 0900	50	Langley Bay
6	29 July 1800	30 July 0900	50	Langley Bay
7	29 July 1800	30 July 0900	100	Langley Bay
8	31 July 1030	31 July 1230	50	Control
9	31 July 1030	31 July 1230	50	Control

TABLE 7.5.5: TOTAL FISH CAUGHT - EPS STUDY

Set No.	Location	Whitefish	Sucker	Pike	Burbot	Lake Trout
1	Control	19	1	0	3	1
2	Control	35	19	0	8	4
3	Langley Bay	2	0	0	0	0
4	Langley Bay	16	1	4	0	0
5	Langley Bay	7	0	6	0	0
6	Langley Bay	6	0	2	0	0
7	Langley Bay	8	0	13	0	0
8	Control	0	0	18	0	0
9	Control					

TABLE 7.5.6: FISH USED FOR SAMPLE ANALYSIS

Fork Length (cm)	Weight (lb)	Sex	Stomach Content	Set No.
Control Pike				
71	6.0	M	void	8, 9
75	7.25	M	whitefish	8, 9
72	7.0	F	pike	8, 9
65	4.5	M	void	8, 9
62	3.5	F	whitefish	8, 9
61	3.75	M	void	8, 9
66	5.0	M	void	8, 9
76	7.0	F	fish bones	8, 9
64	4.5	M	void	8, 9
64	4.0	F	void	8, 9
Langley Bay Pike				
59.2	2.4	M	minnows	4
58	2.1	F	burbot	4
73.5	5.8	M	void	4
55.5	2.1	I	void	4
98	16	F	void	5, 6, 7
93	11	F	void	5, 6, 7
93	17	F	whitefish	5, 6, 7
85	10	F	void	5, 6, 7
89	12	F	void	5, 6, 7
88	10	F	void	5, 6, 7
Control Whitefish				
37.5	1.0	M	sphaerids	1
38.5	1.2	M	sphaerids	1
41.0	1.3	M	sphaerids	1
37.0	0.75	I	sphaerids	1
39.0	1.3	M	sphaerids	1
40.5	1.5	F	sphaerid and snail	1
41.0	1.0	F	sphaerids	1
39.5	1.0	F	void	1
39.5	2.0	F	sphaerids	1
36.0	1.0	M	sphaerids	1
40.0	1.7	F	sphaerids	1
36.0	1.0	I	void	1
42.0	1.2	F	snail	1
36.5	1.0	M	sphaerids	1

TABLE 7.5.6: FISH USED FOR SAMPLE ANALYSIS

Fork Length (cm)	Weight (lb)	Sex	Stomach Content	Set No.
33.0	0.3	I	sphaerids	1
36.0	1.5	M	sphaerids	1
31.0	L 0.3	F	void	1
32.0	0.3	I	void	1
31.5	0.4	I	sphaerids	1
Langley Bay Whitefish				
45.0	2.6	F	snails	3
39.5	1.2	I	snails	3
47.0	2.5	F	insect remains	4
44.0	2.6	F	caddisflies	4
40.0	1.2	M	insect and snail	4
41.5	1.7	M	snails	4
44.5	2.3	M	snails	4
47.0	2.5	F	insect remains	4
48.0	2.5	F	snails	4
49.0	3.0	F	void	4
47.0	3.2	F	snails	4
42.0	1.9	F	snails	4
Control Suckers				
49.0	2.5	M	void	2
45.0	2.4	F	mush	2
39.0	1.4	F	mush	2
44.0	2.2	F	mush	2
41.5	1.6	F	mush	2
40.0	1.6	F	mush	2
40.0	1.2	M	mush	2
37.0	1.1	F	mush	2
43.0	1.8	F	mush	2
43.0	1.9	F	mush	2
Langley Bay Suckers				
43.0	1.5	-	-	4

TABLE 7.5.7: FISH SAMPLES FOR RADIONUCLIDE AND METAL ANALYSIS

Organ	Pike		Whitefish		Sucker	
	L.B.	Control	L.B.	Control	L.B.	Control
Gut content	R	R	R	R	X	R
Ovaries	R	R	R	R	R	R
Bone	R	R	R	R	R	R
Liver	R	R	R	R	R	R
Muscle	R, M	R, M	R, M	R, M	R, M	R, M
Gut	R	R	R	R	R	R
Male gonads	R	R	R	R	X	R
Kidney	R	R	R	R	R	R

R - Radionuclide sample.

M - Metal sample.

X - No sample.

7.5.1.5 Forage Fish

Forage fish were collected by seining in Langley Bay and the Control area. Stickleback were collected from Station 1 for the flux experiment (Section 7.5.1.8). Forage fish samples were submitted for analysis (Table 7.5.8) and collected for identification (Table 7.5.3).

7.5.1.6 Plankton

Net plankton samples were collected using a net with a mouth diameter of 20.3 cm and a mesh size of 64. At each station, one vertical haul was made on each of three consecutive days. The contents of the cup were transferred to a 25 mL vial and preserved with Lugals solution. A list of samples collected is shown in Table 7.5.1.

Nanoplankton were collected at the same time as the net plankton and are included in Table 7.5.1. The nanoplankton samples were taken by dipping the 25 mL vial directly into the surface of the water and preserving with Lugals solution.

7.5.1.7 Benthos

Although attempts were made to collect benthos from Station 3 and at the flux experiment site, insufficient quantities were collected for analysis.

7.5.1.8 Flux Experiment

Two flux experiments and a total uptake experiment were conducted over a five-day period, 21 to 26 July 1983. The flux experiment was intended to measure the flux of dissolved radionuclides into the surficial waters and their subsequent absorption by forage fish. The total uptake experiment was intended to measure the short-term uptake by forage fish in direct contact with the tailings.

TABLE 7.5.8: FORAGE FISH COLLECTED FOR RADIONUCLIDE ANALYSIS

Passive Uptake #1	for radionuclides 26 July 1983
Passive Uptake #2	
Passive Uptake Control	
Total Uptake	
Langley Bay Forage Fish	for radionuclides July 1983
Control Stickleback	
Control Forage Fish	

The flux experiment used 4.5-litre plastic containers with a 10 cm hole cut in the bottom over which a 14 cm diameter 0.45 um cellulose acetate filter was attached with contact cement. A plastic flange was glued around the bottom of the bottle so that it projected 5 cm downward. When in position, this flange was imbedded into the sediment eliminating lateral water flow between it and the filter. Control containers were 4.5-litre plastic containers with solid bottoms. All containers were filled with filter-sterilized water from Lake Athabasca, west of Station 2 (Figure 7.5.1). The forage fish used in this experiment were collected by seining at Station 1 (Figure 7.5.1).

The first flux experiment measured passive diffusion of radionuclides from the tailings into the surficial waters. Three bottles with filter bottoms were filled with water and set on the tailings for five days. As a control sample, a bottle with a solid bottom was left on the tailings for the same time period. At the end of five days, the bottles were recovered and the water transfered to new bottles. The samples were preserved and submitted for radionuclide analysis.

The second flux experiment was passive uptake of radionuclides by forage fish. In this experiment, six bottles with a filter bottom and three bottles with a solid bottom were used. These bottles were filled with water and six fish each and placed on the tailings for a five-day period. All bottles were aerated with pure oxygen for three minutes each morning and evening. At the end of five days, the fish were removed and combined to make two samples of 18 fish each for the filter-bottomed bottles and one sample of 18 fish for the solid-bottomed bottles. Water samples were taken from one solid-bottom and three filter-bottom bottles for radionuclide analysis. The remaining bottles of water were discarded.

The total uptake experiment involved the use of a corral to keep forage fish in an area above and in contact with the tailings. The corral was constructed of window screening stretched around three stakes. Forage fish were placed into the corral and left for five days. At the end of this time, the fish were collected and submitted for radionuclide analysis.

A sample of the tailings, of the water used in the plastic containers, and of the forage fish from Sampson Island were submitted for radionuclide analysis to supply background information.

7.5.2 Laboratory Procedures

All routine chemical and metal analyses were performed by the EPS Chemistry Laboratory, Edmonton, Alberta. All radionuclide analyses were performed by CCIW, Burlington, Ontario. EPS methods follow EPA (1979) for water, Arafat and Chau (1977) for sediments, and M. Hendzel (pers. comm., CCIW) for fish. The fish method for trace metals involves a nitric/peroxide digestion followed by Atomic Absorption Spectrometry. CCIW methods follow Joshi and Durham (1976) and Durham and Joshi (1980) for Ra-226 and Pb-210, and Durham and Joshi (1979) for thorium isotopes.

7.5.3 QA/QC Program

Internal quality assurance at CCIW includes regular background checks and reference sample determinations (approximately every three months). CCIW participates in interlaboratory studies with radionuclide materials (U.S. EPA, IAEA) every two to three months.

7.6 REGIONAL DATA FROM PUBLISHED SOURCES

There exists a relatively large body of data relating to aquatic and terrestrial biota of the Gunnar tailings and surrounding environment. Thus, a major objective of the biology component was to compile these data and evaluate their suitability for inclusion in an environmental model.

Data compiled in this study are summarized by sample type, location and author(s) in Volume 1. Actual data are listed in the data tables of this section.

Few authors individually present sufficient data for complete characterization of spatial and temporal variability in the tailings environments of the Gunnar area. However, collectively, their data, with those of the present study, provide an adequate spatial coverage. Kalin (1981, 1982) presents the greatest quantity of physical-chemical data. Data on biological concentrations of radionuclides in tailings areas are available in Kalin (1981, 1982) and EPS (1981). These data are important for validation of food chain transport models.

Since most modelling efforts are directed toward prediction of impacts beyond the tailings site, environmental data from control sites are required. No single control site has been adequately characterized. Possible candidates for control sites include Fredette Lake and Lake Athabasca. These lakes have been used as controls in a number of studies and are well documented, although it should be noted that Fredette Lake is more shallow than many other small lakes in northern Saskatchewan and, therefore, dominated by shallow water fish species such as northern pike. Surface water and sediment chemistry data, as well as biological data on tissue levels of radionuclides, are available for Fredette Lake in EPS (1978) and Swanson (1982), and for Lake Athabasca in EPS (1981), Kalin (1981) and Tones (1982).

Biological compartments are represented in the literature both by radiochemical data and by species inventory and abundance data. The latter information contributes to model development by ensuring that representative food chains and land use patterns are incorporated into biological model components. Harms and Fraser (1982) provide a good vegetation map of the Gunnar tailings areas, based on a 1981 survey. Faunal assemblages are best described in EPS (1981).

An index to the data tables of this section, and their sources, is provided on the following page.

7.6 REGIONAL DATA FROM PUBLISHED SOURCES (Gunnar Area and Vicinity)

Figure 7.6: Map of Historical Sampling Locations

7.6.1 Aquatic Ecology

Tables 7.6.1 to 7.6.4	EPS, 1978
Tables 7.6.5 to 7.6.10	EPS, 1981
Tables 7.6.11 to 7.6.21	Tones, 1982
Tables 7.6.22 to 7.6.32	Swanson, 1982
Figure 7.6.1	Tones, 1982

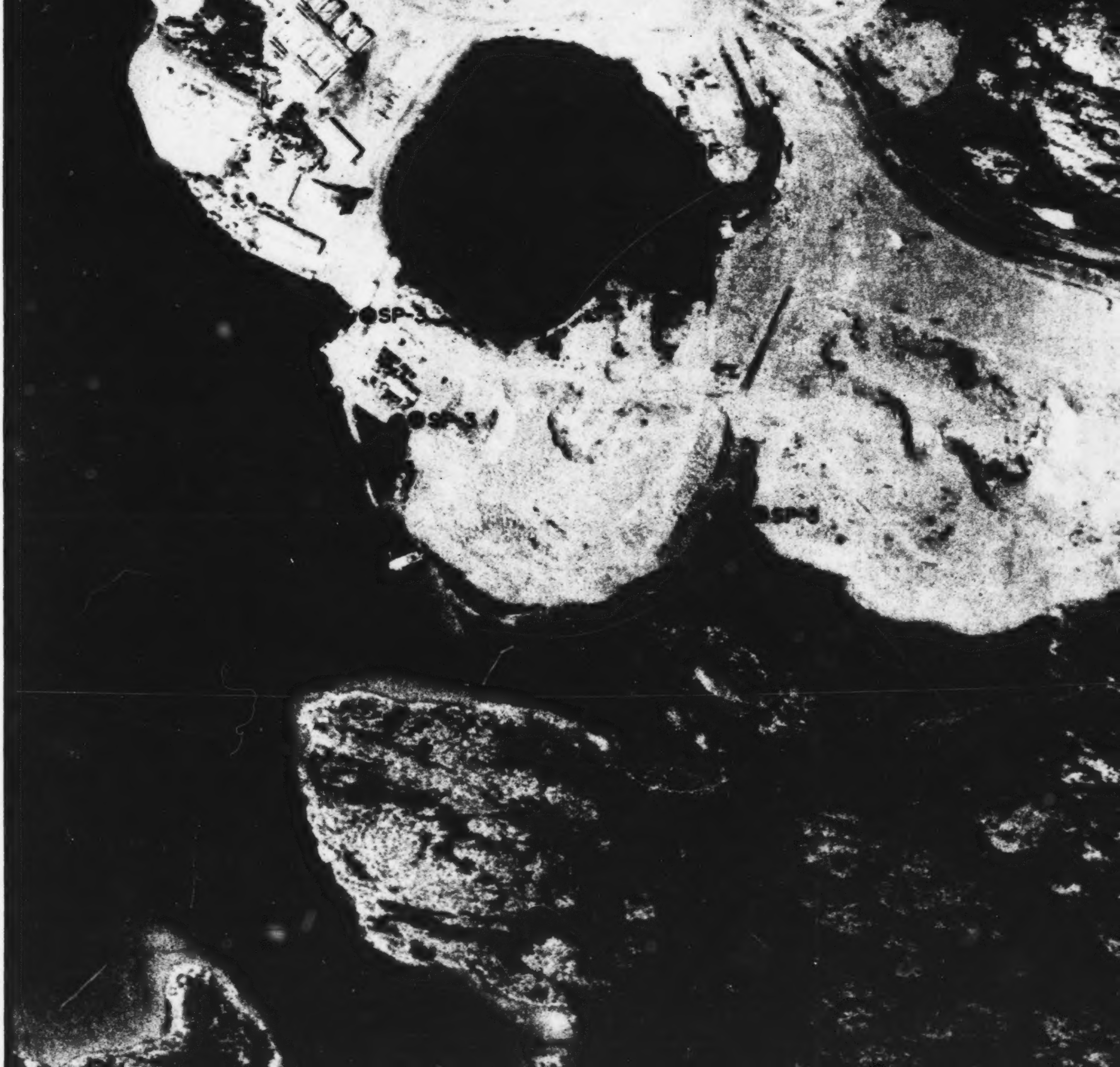
7.6.2 Vegetation

Table 7.6.33	Kalin, 1982
Table 7.6.34	Harms and Fraser, 1982
Table 7.6.35	Swanson and Pipe, 1982

7.6.3 Soils and Associated Vegetation Analyses

Tables 7.6.36 to 7.6.38	Redman and Frankling, 1982
Tables 7.6.39 to 7.6.41	Kalin, 1982
Tables 7.6.42	Swanson and Pipe, 1982
Figures 7.6.2 to 7.6.4	Kalin, 1982
Tables 7.6.43 to 7.6.45	Kalin, 1981

FIGURE 7.6: MAP OF HISTORICAL SAMPLING LOCATIONS



SP-3
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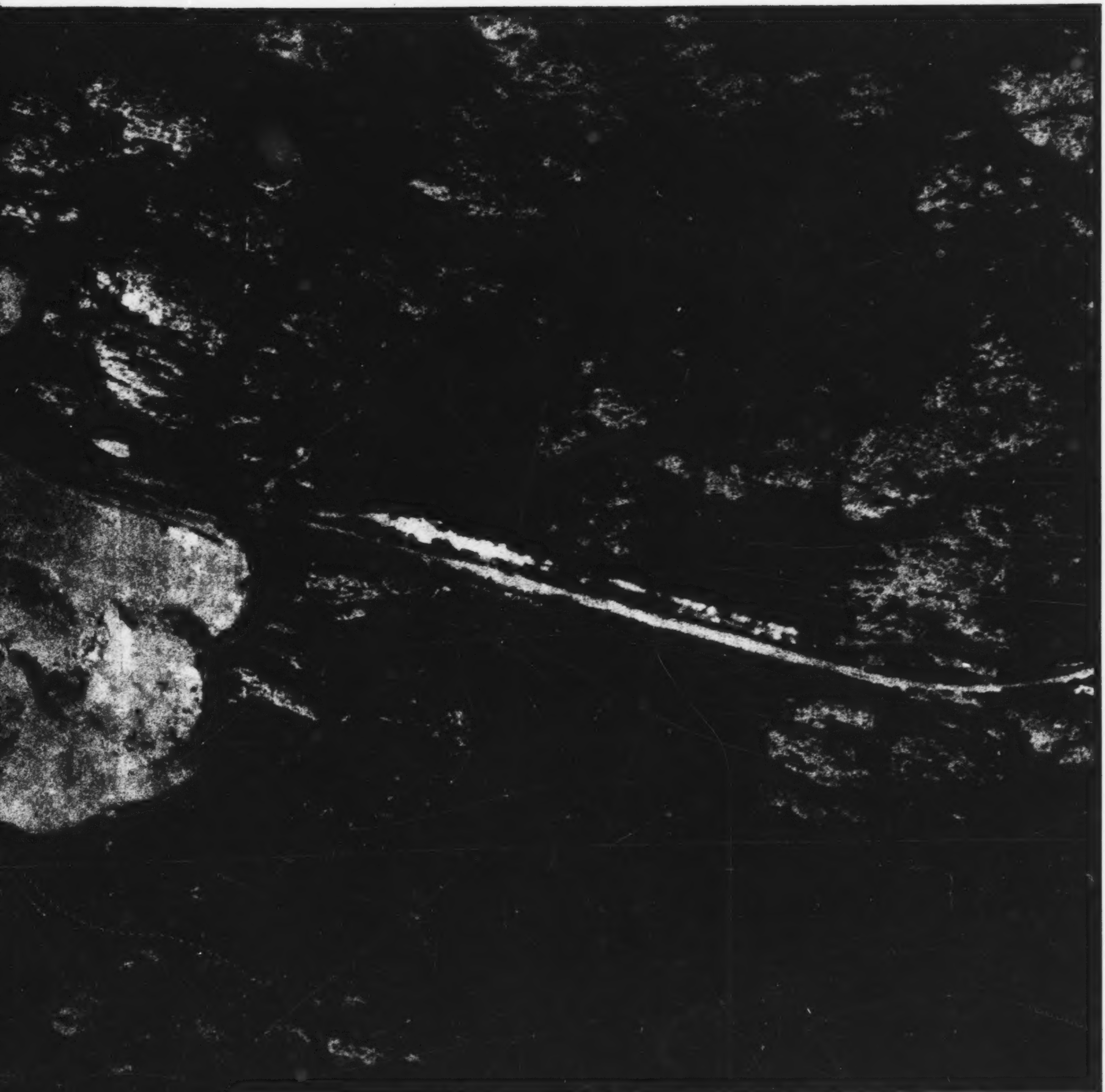

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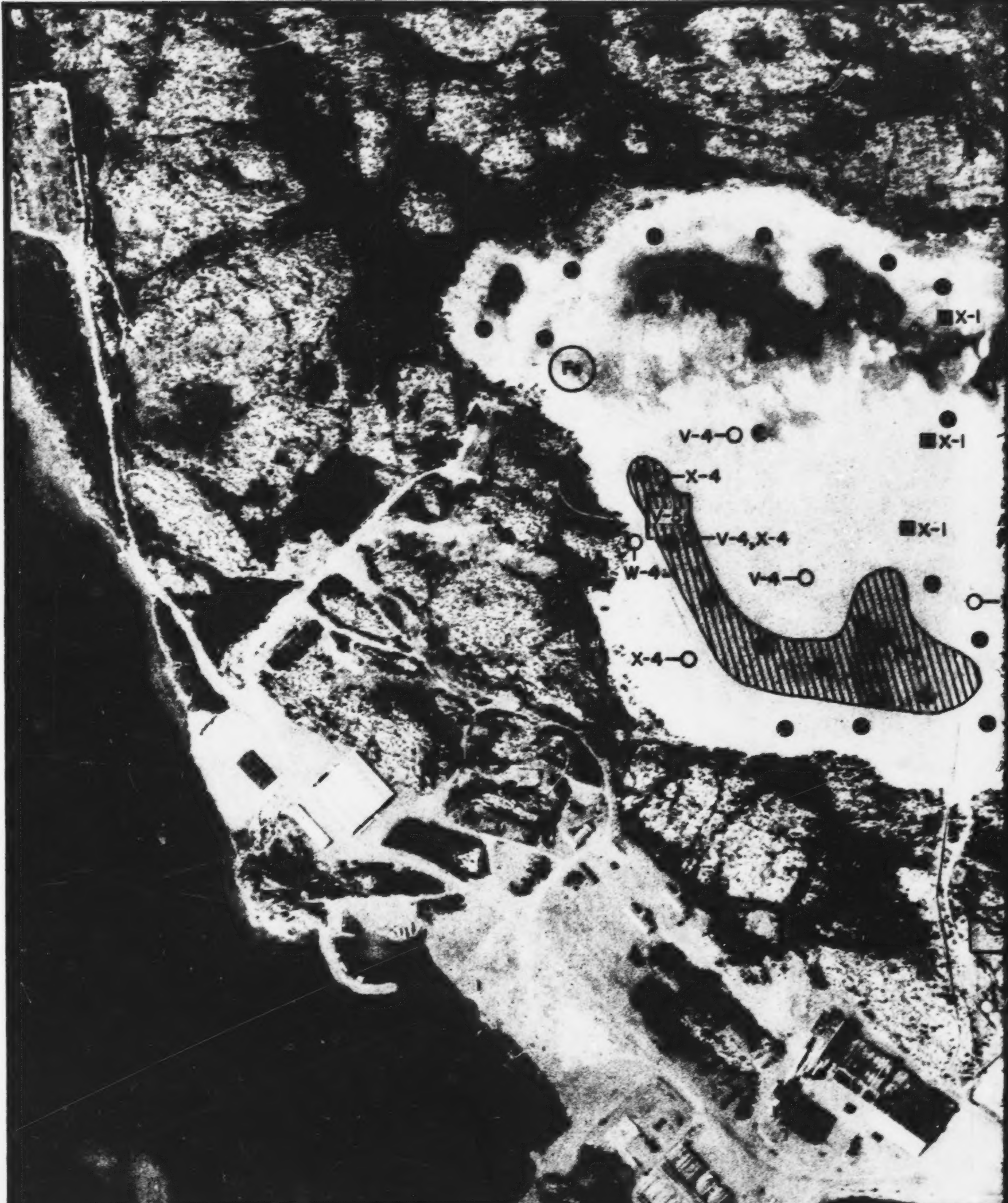
HISTORICAL SAMPLING STATIONS

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE	DRAWN BY PMG	FIG. 7.6
DATE 31·01·86	APPROVED BY	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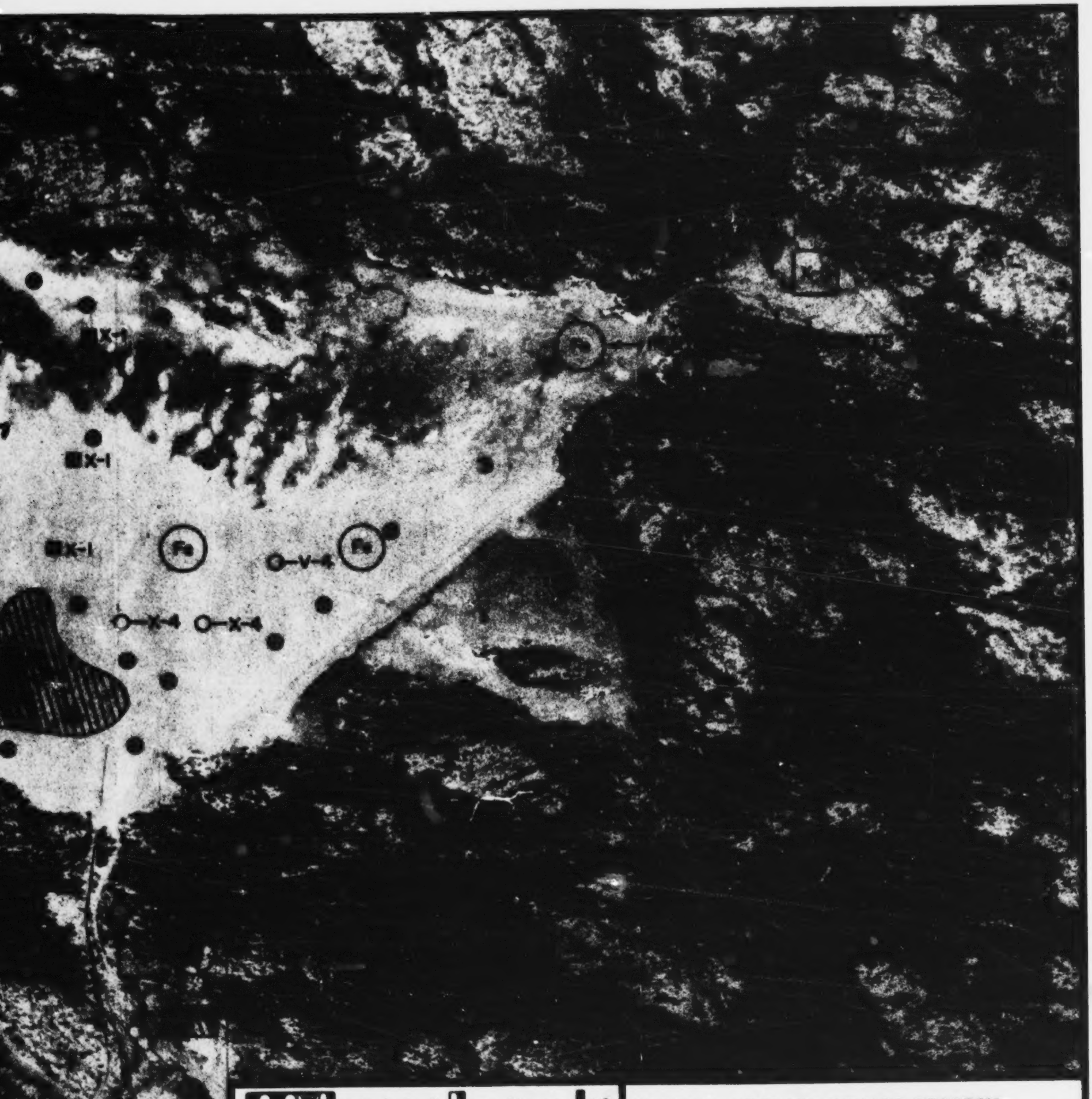

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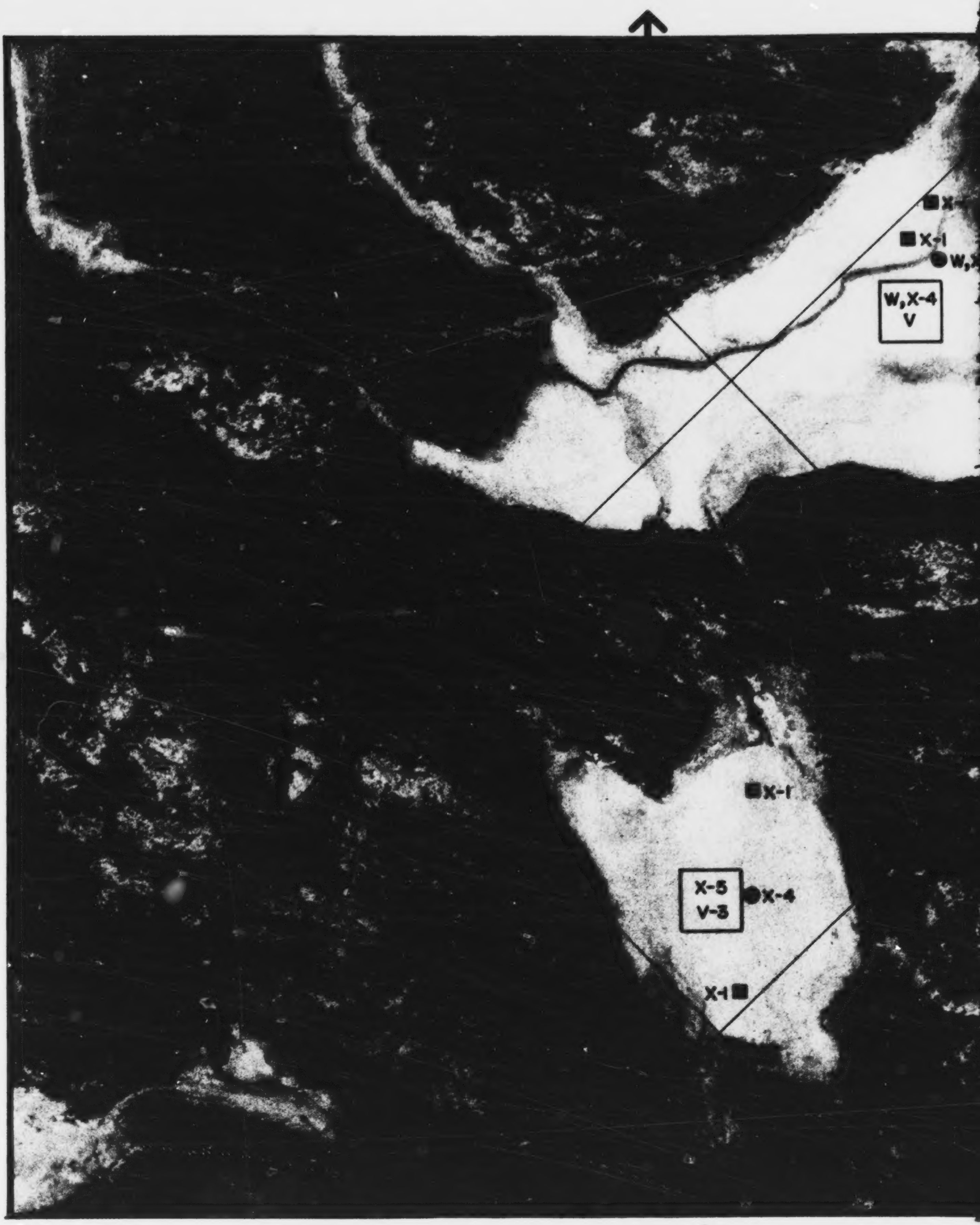
HISTORICAL SAMPLING SITES
1981, 1982

NATIONAL URANIUM TAILINGS PROGRAM

GUNNAR FIELD STUDY

SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE	DRAWN BY PMG	FIG. 7.6
DATE 05·02·86	APPROVED BY	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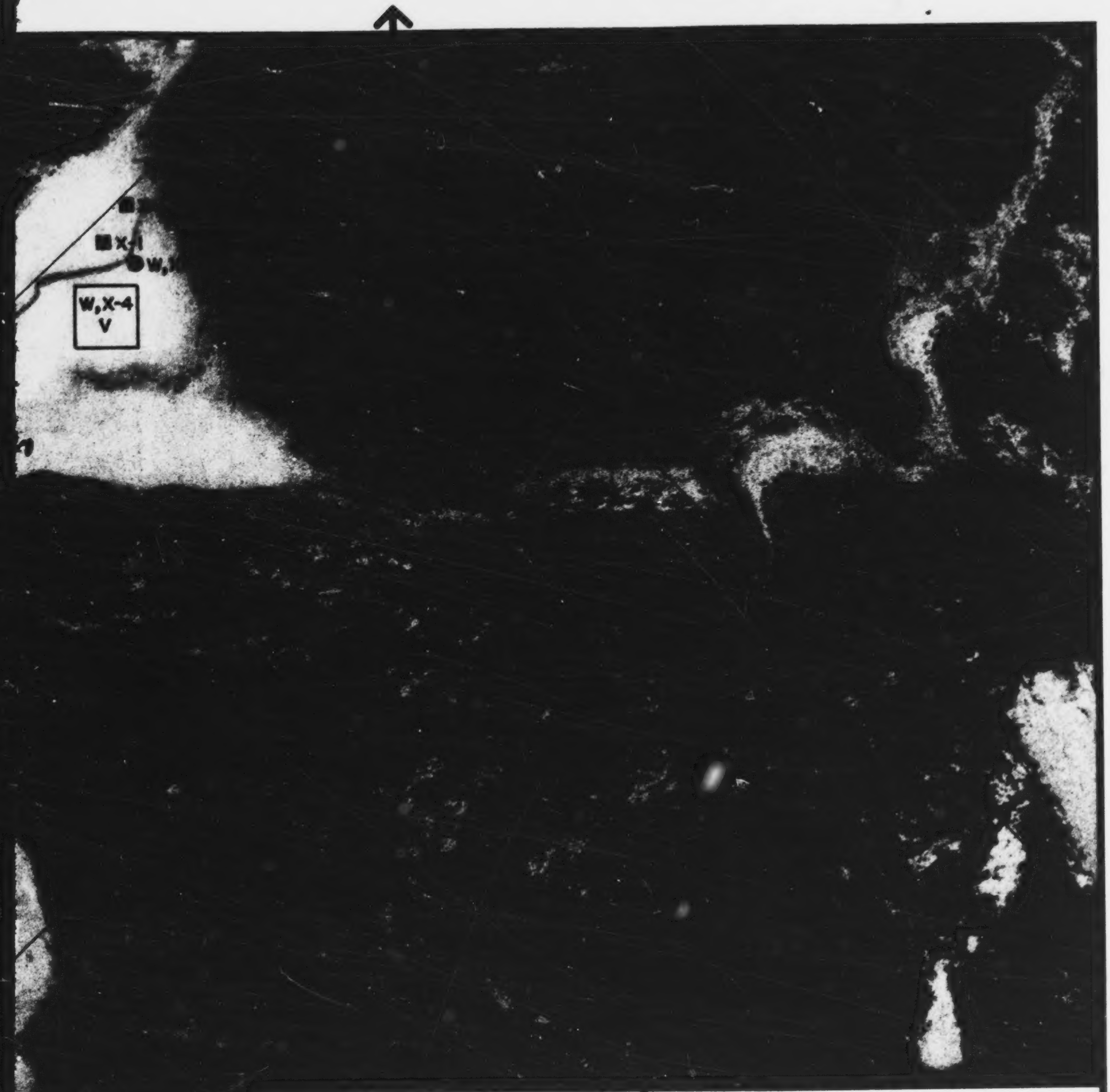
X-1



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SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE	DRAWN BY PMG	FIG. 7.6
DATE 05·02·86	APPROVED BY	

7.6.1 Aquatic Ecology

TABLE 7.6.1: ZOOPLANKTON COLLECTED AT STATION F1 IN FREDETTE LAKE, 10 JUNE 1976

Taxa	Quantity
O. Copepoda	
S.O. Calanoida	
Epischura lacustris	32
S.O. Cyclopoida	
Cyclops scutifer	536
Immature	11104
Nauplii	437
Copepodids	662
O. Cladocera	
Daphnia sp.	126
Bosmina longirostris	47
P. Rotifers	
Keratella hiemalis	79
K. cochlearis	158
Kellicottia sp.	2158
Filinia sp.	252
F. longiseta	362
TOTAL ...	15969

TABLE 7.6.2: FIELD AND LABORATORY ANALYSES OF WATER AND WASTEWATER COLLECTED AT FREDETTE LAKE IN JUNE AND SEPTEMBER 1976

	Field Analysis					Radionuclides (pCi/L)						
Date (day/mo)	D.O. (mg/L)	pH	Temp. (^oC)	Cond. (umhos)	Flow (m^3/min)	Ra-226 (E)	Ra-226 (3 u)	Ra-226 (0.45 u)	Pb-210 (E)	Pb-210 (3 u)	Th (ug/L)	U (ug/L)
9/6		6.6	15	68		L 0.1					L 3	6
15/9	10.8	7.4	12	60								

	Metals (mg/L)									
	Zn	Cu	Pb	Fe	Hg	Ba	Cd	Ni	V	Na
9/6	L 0.005	L 0.015	L 0.10	0.04	L 0.0002	L 0.10	L 0.014	L 0.02	0.6	2

	Other Chemical Parameters (mg/L)									
	TSS	VSS	Total Solids	Total Hardness	Ca Hardness	pH	Total Alkalinity	Chloride	Sulphate	Total Conductivity (umhos)
9/6	L 1	L 1	54	38	20	7.0	35	1.8	L 5	60

TABLE 7.6.3: ANALYSES OF SEDIMENTS COLLECTED FROM FREDETTE LAKE IN 1976

Location	Date Sampled	Ca (mg/g)	Ba (mg/g)	Cd (mg/g)	Hg (mg/kg)	Ra-226 (pCi/g)
Fredette Lake						
F1	15 September 1976	2.38	L 0.1	L 0.01	0.009	1.8

Note: a) Ca, Ba and Cd analyses performed by EPS Chemistry Laboratory in Edmonton; Ra-226 by Radiation Protection Bureau, Health and Welfare Canada.

b) Hg analyses performed by Water Quality Laboratory, Inland Waters Directorate in Calgary.

c) Concentrations on a dry weight basis.

TABLE 7.6.4: RADIONUCLIDE ANALYSIS OF FLESH AND SKELETAL MATERIAL OF FISH COLLECTED FROM FREDETTE LAKE IN 1976

Location	Date	No.	Species	Flesh Weight (g)	Bone Weight (g)	Ash Weigh (g)	Ra-226 (pCi/g ash)	Pb-210 (pCi/g ash)
Fredette Lake (F1)	10 Jun 76	2	lake whitefish	122.6		2.6	2.4	
					31.8	3.8	L 0.1	
	15 Sep 76	40	lake whitefish	197.7		3.2	0.8	1.8
					17.5	3.2	0.3	
	15 Sep 76	46	lake whitefish	223.0		4.0	0.8	
					15.7	2.4	0.2	
	10 Sep 76	3	northern pike	273.3		3.1	2.8	
					40.2	8.7	L 0.1	
	15 Sep 76	32	northern pike	436.4			0.3	L 0.1
					34.9	7.8	0.2	
	15 Sep 76	37	northern pike	454.2		5.2	0.3	
					48.7	10.2	L 0.1	
	15 Sep 76	30	lake trout	345.0		4.1	0.5	
					140.3	21.0	L 0.1	
	15 Sep 76	31	lake trout	727.7		8.9	1.3	
					59.2	9.9	0.1	

TABLE 7.6.5: HEAVY METAL AND RADIONUCLIDE ANALYSES OF SEDIMENTS COLLECTED FROM LANGLEY BAY AND LAKE ATHABASCA, JULY 1978

STATION		PARAMETER (results on a dry weight basis)												
		As (μg/g)	Cd (μg/g)	Cu (μg/g)	Hg (μg/g)	Mo (μg/g)	Ni (μg/g)	Pb (μg/g)	V (μg/g)	Zn (μg/g)	Ra226 (pCi/g)	Pb210 (pCi/g)	Th230 (pCi/g)	Unat (μg/g)
LANGLEY BAY														
Station	Sample													
1 (fines)	A	16	<4	71		<200	48	280	<1000	73	1240	2000	1810	
1	A												305[3]	35[3]
	A	9	<4	94		<200	38	100	<1000	58	140	300	181	405
	B	26	<4	113	<0.05	<200	42	160	<1000	70	235	389	904	489
2	A**	14	<4	77		<200	52	200	<1000	105	425	450	484	55.0
	B**	7	<4	46		<200	42	180	<1000	59	317	402	387	52.4
3	A	21	<4	61	<0.05	<200	35	240	<1000	49	4.0	7.7	7.9	69.9
	B	18	<4	34		<200	42	220	<1000	60	1000	1300	1200	66.2
	B										694[3]	540[3]	432[3]	50[3]
4	A*	340	<4	250		<200	685	300	1300	745	1300	722	2000	452
	B	290	<4	180		<200	196	260	<1000	238	347	667	565	376
LAKE ATHABASCA														
Station	Sample													
5	A	10	<4	22	<0.05	<200	34	60	<1000	28	16	96	107	199
6	A	<5	<4	10		<200	57	<20	<1000	<4	8.1	21	12	25.7
7	A	10	<4	6		<200	38	<20	<1000	32	1.6	1.9	0.6	3.3
	B	10	<4	<4	<0.05	<200	30	20	<1000	18	0.9	1.9	0.8	3.1

* 2 samples combined
** 3 samples combined
[1] SRC
[2] AECL
[3] NEM

Ra^{226}, Pb^{210}, Th^{230} Analyses performed by SRC unless otherwise indicated
U^{nat} Analyses performed by AECL unless otherwise indicated

TABLE 7.6.6: PERCENT COMPOSITION BY TOTAL DENSITY AND TOTAL BIOMASS OF MAJOR PHYTOPLANKTON GROUPS COLLECTED FROM LANGLEY BAY AND LAKE ATHABASCA, JULY 1979

STATION	1		2		3		4T*		4B*		5T*		5B*		6T*		6B*		7	
BOTTLE NO.	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3
Percent composition of major groups by total density **																				
Chlorophyta	7.8 (135)	- -	9.6 (91)	6.0 (34)	12.1 (106)	4.6 (20)	4.1 (50)	3.6 (26)	7.5 (66)	6.2 (55)	1.2 (8)	2.3 (21)	2.4 (25)	- -	2.6 (15)	3.9 (43)	1.1 (11)	0.6 (3)	4.7 (28)	4.3 (28)
Cyanophyta	- -	- -	- -	- -	- -	7.8 (34)	17.6 (213)	38.5 (280)	6.4 (56)	23.8 (212)	15.5 (101)	17.3 (155)	17.1 (175)	- -	13.0 (76)	22.7 (298)	15.9 (162)	8.3 (42)	14.6 (88)	34.3 (225)
Chrysophyta	72.1 (1250)	70.5 (1206)	18.2 (172)	6.5 (37)	26.5 (233)	21.5 (94)	19.3 (234)	10.0 (73)	30.1 (263)	19.4 (173)	74.0 (483)	65.5 (588)	69.6 (713)	88.2 (699)	63.3 (369)	49.1 (537)	39.0 (600)	62.1 (316)	50.8 (306)	35.5 (233)
Bacillariophyta	14.3 (248)	19.9 (341)	38.6 (364)	45.1 (256)	44.4 (390)	39.8 (174)	18.7 (227)	23.9 (174)	18.3 (160)	16.5 (147)	7.0 (46)	12.0 (108)	8.1 (83)	9.1 (72)	17.3 (101)	17.1 (187)	20.9 (213)	19.7 (100)	27.4 (165)	23.8 (156)
Pyrrophyta	- -	0.4 (7)	- -	1.1 (6)	1.6 (14)	- -	- -	0.8 (6)	- -	- -	- -	- -	- -	- -	- -	- -	0.3 (3)	0.6 (3)	- -	0.2 (1)
Cryptophyta	5.8 (100)	9.1 (156)	33.6 (317)	41.4 (235)	15.4 (135)	26.3 (115)	40.4 (490)	23.2 (169)	37.7 (330)	34.0 (303)	2.3 (15)	2.9 (26)	2.8 (29)	2.8 (22)	3.8 (22)	7.2 (79)	2.8 (28)	8.8 (45)	2.5 (15)	2.0 (13)
Percent composition of major groups by total biomass ***																				
Chlorophyta	4.5 (10.3)	- -	7.2 (11.2)	1.6 (1.9)	6.1 (10.2)	4.3 (2.3)	2.4 (4.0)	2.6 (2.5)	8.2 (13.6)	2.5 (4.1)	0.7 (0.6)	1.3 (1.6)	1.7 (2.1)	- -	1.2 (1.1)	1.9 (3.2)	0.5 (1.1)	0.2 (0.2)	2.1 (2.6)	
Cyanophyta	- -	- -	- -	- -	- -	0.6 (0.3)	12.7 (21.3)	3.0 (2.8)	0.3 (0.6)	10.6 (17.3)	1.3 (1.0)	1.3 (1.6)	1.4 (1.8)	- -	0.8 (0.8)	1.5 (2.5)	0.7 (1.6)	0.1 (0.2)	0.2 (0.9)	
Chrysophyta	23.9 (78.0)	30.2 (84.3)	12.2 (18.9)	3.1 (3.7)	8.9 (14.9)	12.0 (6.4)	6.7 (11.2)	5.9 (5.6)	17.5 (28.8)	35.3 (57.7)	78.8 (63.5)	59.2 (72.5)	67.2 (83.8)	76.8 (80.7)	50.6 (49.3)	41.8 (71.5)	37.9 (88.8)	45.1 (45.9)	35.3 (42.6)	
Bacillariophyta	36.4 (83.8)	43.9 (122.5)	50.4 (78.4)	64.5 (76.8)	53.1 (89.1)	67.4 (36.1)	38.1 (64.1)	46.8 (43.9)	38.6 (63.6)	25.1 (41.0)	8.3 (6.7)	30.0 (36.7)	23.2 (28.9)	14.1 (14.8)	44.8 (43.6)	42.2 (72.1)	58.5 (137.2)	43.6 (44.5)	60.3 (72.8)	
Pyrrophyta	- -	3.8 (10.5)	- -	3.8 (4.6)	6.3 (10.6)	- -	- -	4.9 (4.5)	- -	- -	- -	- -	- -	- -	- -	- -	1.0 (2.3)	2.2 (2.3)	- -	
Cryptophyta	25.2 (58.1)	22.1 (61.7)	30.2 (47.0)	26.9 (32.0)	25.7 (43.1)	15.7 (8.4)	40.3 (67.8)	36.8 (34.5)	35.4 (58.5)	26.5 (43.3)	10.8 (8.7)	8.2 (10.0)	6.5 (8.1)	9.1 (9.6)	2.7 (2.6)	12.5 (21.6)	1.4 (3.4)	8.7 (8.9)	1.5 (1.8)	
Total cells/ml	1733	1710	944	568	878	432	1214	728	875	890	653	898	1025	793	583	1094	1017	509	602	—
Total biomass mg/m^3	203.2	279.0	155.5	119.0	167.9	53.5	168.4	93.8	165.1	163.4	80.5	122.4	124.7	105.1	97.4	170.9	234.4	102.0	120.7	110.3
No. of species	20	21	27	21	25	22	22	24	28	21	16	15	22	12	18	21	23	15	25	22
Diversity index	2.94	3.00	3.37	2.44	3.89	3.29	3.06	2.90	3.55	3.31	2.64	2.83	2.78	2.06	3.17	3.25	3.19	2.77	3.45	2.99

* T = TOP, B = BOTTOM

** TOTAL DENSITY (CELLS/ml) IN PARENTHESES

*** TOTAL BIOMASS (mg/m^3) IN PARENTHESES

TABLE 7.6.7: ZOOPLANKTON COLLECTED FROM LANGLEY BAY AND LAKE ATHABASCA, 12 JULY 1978

TAXA	STATION						
	LANGLEY BAY				LAKE ATHABASCA		
	1	2	3	4	5	6	7
O. Copepoda							
S.O. Cyclopoida							
Cyclops bicuspidatus	48	226	374	1124	28	60	12
S.O. Calanoida							
Diaptomus ashlandi	420	58	530	208	1216	328	237
Epischura nevadensis	14	10	68	20	12	4	2
Copepodids	350	10	38	9	488	100	36
Nauplii	1274	1344	1816	2288	404	280	96
O. Cladocera							
Bosmina coregoni		2	432	516	24	28	4
Daphnia longiremus		14	98	175			
Holopedium gibberum		6	26	6			
Sida crystallina		2					
P. Rotifera							
Conochilus sp.							15
Brachionus sp.				4			
Kellicotia longispina	74	468	260	996	52	140	75
Keratella canadensis			2	32			
K. cochlearis	2	24	44	60	58	20	5
Polyarthra sp.	44	52	28	52	8	20	
Trichocerca sp.					4		
Total No. Organisms	2226	2216	3716	5491	2294	980	482
Total No. Taxa	8	12	12	13	10	9	9
Diversity	1.78	1.74	2.36	2.34	1.89	2.44	2.11

NOTE: Numbers represent the total catch in a single net haul at each station

TABLE 7.6.8: BENTHIC INVERTEBRATES (#/m^2) COLLECTED FROM LANGLEY BAY AND LAKE ATHABASCA, 10 JULY 1978

TAXA	STATION						
	LANGLEY BAY				LAKE ATHABASCA		
	1	2	3	4	5	6	7
C. Insecta							
O. Diptera							
F. Ceratopogonidae		44					
F. Empididae		163	15				15
F. Chironomidae	1319	148	59	281	89	104	1570
C. Oligochaeta				874	148		1437
C. Crustacea							
O. Amphipoda							
F. Haustoriidae							
Pontoporeia affinis				44	548	1719	4222
F. Talitridae							
Hyalella azteca							44
C. Gastropoda							
F. Valvatidae							
Valvata sp.		15	30	59	15		44
C. Pelecypoda							
F. Sphaeriidae							
Pisidium sp.				59	74	89	356
Sphaerium sp.						15	133
Total no. Organisms	1319	370	104	1317	874	1927	7821
Total no. Taxa	1	4	3	5	5	4	8
Diversity ($\bar{d}$)	0	1.60	1.38	1.44	1.59	0.68	1.80

TABLE 7.6.9: FISH COLLECTED BY GILL NET FROM LANGLEY BAY (LAKE ATHABASCA), 09 JULY 1978

SPECIES	FORK LENGTH (mm)	WEIGHT (g)	SEX	AGE	WET WEIGHT OF FLESH (g)	ASH WEIGHT (g)	RADIONUCLIDE CONTENT OF FLESH (ash)			
							pCi/g of ash			ppm
							Ra226	Pb210	Th230	U nat
Northern Pike	430	600	immature	6+						
Northern Pike	484	800	immature	6+						
Northern Pike	552	1250	M	8+						
Northern Pike	564	1270	F	7+	306	3.27	2.0	1.4	<0.3	0.1
Northern Pike	570	1350	M	7+						
Northern Pike	630	1870	M	11+	219	2.00	3.4	2.0	0.3	0.1
Northern Pike	628	1860	F	8+	242	2.80	1.4	2.0	<0.3	0.1
Northern Pike	644	2090	M	8+	259	2.74	1.7	1.3	<0.3	<0.1
Northern Pike	740	3060	M	11+	227	3.00	0.5	1.7	<0.3	0.2
Northern Pike	781	4400	M	11+						
Northern Pike	818	4870	F	12+	236	2.60	0.6	0.7	<0.3	0.1
Lake Whitefish	360	630	F	6+	178	2.3	8.0	4.7	6.4	5.0
Lake Whitefish	421	970	M	9+	262	2.97	5.5	9.4	4.2	1.6
Lake Whitefish	427	1020	M	8+	254	2.85	6.4	3.6	2.8	2.2
Lake Whitefish	435	1010	M	9+	304	3.08	8.4	7.1	9.2	4.4
Lake Whitefish	440	1230	F	9+	282	3.50	1.2	7.8	0.7	1.2

TABLE 7.6.10: RADIONUCLIDE CONCENTRATIONS IN FISH FLESH - FREDETTE LAKE AND LANGLEY BAY

	Ra-226 (pCi/g ash)	Pb-210 (pCi/g ash)	Th-230 (pCi/g ash)	U-238 (ug/g ash)
Northern Pike				
Fredette Lake[1]	0.3-2.8	0.1		
Langley Bay	1.5-3.4	0.7-2.0	0.3-0.3	0.1-0.2
Lake Whitefish				
Fredette Lake[1]	0.8-2.4	1.8		
Langley Bay	1.2-8.4	3.6-9.4	0.7-9.2	1.2-5.0

[1] Ruggles and Rowley (EPS, 1978).

TABLE 7.6.11: DEPTH PROFILES OF TEMPERATURE, DISSOLVED OXYGEN AND SPECIFIC CONDUCTIVITY, GUNNAR OPEN PIT

Depth (m)	August 23, 1981				September 20, 1981				November 8, 1981			
	Temp. (°C)	Diss. Oxygen (mg/L)	Specific Conductivity (µmhos/cm)*	% Satur-ation	Temp. (°C)	Diss. Oxygen (mg/L)	Specific Conductivity (µmhos/cm)*	% Satur-ation	Temp. (°C)	Diss. Oxygen (mg/L)	Specific Conductivity (µmhos/cm)*	% Satur-ation
Surface	19.1	8.5	306	94.8	10.3	8.5	335	77.3	0.8	9.9	404	70.0
1	19.1	8.5	308	94.8	10.3	8.3	335	76.2	0.8	9.7	404	69.0
2	19.0	8.5	308	93.7	10.3	8.2	335	75.2	0.8	9.6	404	68.0
3	18.4	8.5	310	92.7	10.3	8.1	337	74.2	0.8	9.5	412	67.5
4	18.1	8.1	315	88.6	10.3	8.1	337	74.2	1.2	9.3	421	67.0
5	15.9	6.5	338	67.0	10.3	8.0	338	73.1	1.2	9.2	422	67.0
6	11.3	5.8	342	53.6	10.3	8.0	342	73.1	--	--	--	--
7	8.5	4.7	378	41.2	10.3	7.8	342	71.1	--	--	--	--
8	6.3	2.5	390	20.6	10.0	7.4	350	67	--	--	--	--
9	5.4	1.7	390	13.4	7.9	2.6	352	21.6	--	--	--	--
10	4.9	1.7	400	12.9	4.9	0.4	386	2.6	1.6	8.8	--	63.9
11	4.5	1.8	405	13.9	4.1	0.4	375	2.1	--	--	--	--
12	4.0	1.9	410	14.4	3.9	0.5	390	3.6	--	--	--	--
13	3.8	2.2	412	16.5	3.9	0.5	390	3.6	--	--	--	--
14	4.0	2.3	410	17.6	3.5	0.5	395	5.2	--	--	--	--
15	3.5	2.3	423	17.5	3.5	0.3	395	3.1	1.9	8.3	411	60.8
16	3.5	2.2	--	16.5	3.5	0.3	--	2.1	--	--	--	--
17	3.5	2.2	--	16.5	3.4	0.3	--	2.1	--	--	--	--
18	3.5	1.8	--	13.4	3.4	0.3	--	2.1	--	--	--	--
19	3.5	1.6	--	11.9	3.3	0.3	--	2.1	--	--	--	--
20	3.5	1.6	423	11.9	3.3	0.3	390	2.1	2.0	7.7	400	56.7
25	3.5	1.4	423	10.3	3.3	0.3	390	2.1	2.3	6.8	406	51.0

*Corrected to 25° C.

TABLE 7.6.11: DEPTH PROFILES OF TEMPERATURE, DISSOLVED OXYGEN AND SPECIFIC CONDUCTIVITY, GUNNAR OPEN PIT

Depth (m)	August 23, 1981				September 20, 1981				November 8, 1981			
	Temp. (°C)	Diss. Oxygen (mg/L)	Specific Conductivity (µmhos/cm)*	% Saturation	Temp. (°C)	Diss. Oxygen (mg/L)	Specific Conductivity (µmhos/cm)*	% Saturation	Temp. (°C)	Diss. Oxygen (mg/L)	Specific Conductivity (µmhos/cm)*	% Saturation
30	3.5	1.4	423	10.3	3.3	0.3	390	2.1	3.0	5.3	400	40.2
35	3.5	1.35	423	9.8	--	--	--	--	3.1	4.1	411	30.9
40	3.5	1.3	423	9.3	3.3	0.3	390	2.1	3.1	3.7	411	27.8
45	3.5	1.3	--	9.3	--	--	--	--	3.1	2.8	411	21.1
50	3.5	1.3	440	9.3	3.3	0.2	390	1	3.1	2.0	411	14.9
55	3.5	1.3	440	9.3	--	--	--	--	3.1	0.6	411	4.1
60	3.5	1.28	440	9.3	3.3	0.2	390	1	3.1	0.4	411	3.6
65	--	--	--	--	--	--	--	--	3	0.7	411	4.6
67.5	--	--	--	--	--	--	--	--	2.1	0.2	455	1.0
70	3.5	1.2	465	8.2	4.0	.03	390	2.1	3	0.7	430	4.6
75	3.8	1.8	502	11.9	4.0	0.3	436	2.1	3	0.7	463	4.6
77.5	--	--	--	--	--	--	--	--	3.1	1.2	520	1.0
80	3.6	2.3	782	17.5	4.5	0.4	700	3.1	3	0.7	638	4.6
85	7.6	2.5	1321	20.6	--	--	--	--	3	0.3	977	2.1
90	5.4	1.3	2041	10.3	5.0	0.3	1875	2.1	3.4	1.5	1864	1.6
95	--	--	--	--	--	--	--	--	3.4	0.5	2000	1.0
100	4.6	1.5	2128	11.3	5.0	0.3	1875	2.1	3.4	0.5	2005	1.0
105	--	--	--	--	5.1	0	1936	0	3.6	0.5	1960	1.0
108	4.6	1.2	2128	8.8	5.3	1.3	1896	10.3	--	--	--	--
108.5	--	--	--	--	--	--	--	--	3.4	1.2	2000	8.2
109	5.5	3.6	2102	28.8	--	--	--	--	--	--	--	--
110 (bottom)	--	--	--	--	--	--	--	--	--	--	--	--

*Corrected to 25° C.

TABLE 7.6.12: WATER QUALITY FIELD DATA, GUNNAR OPEN PIT, AUGUST TO NOVEMBER 1981

Site	Date	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (mmhos/cm)	pH	EH
Gunnar Pit	23-08-81	1	18.5	8.8	328	9.5	--
		7	8.3	5.7	385	7.6	--
		50	6.0	3.0	410	7.2	--
		85	6.0	3.4	1400	7.2	--
		107	6.2	2.9	2200	7.2	--
	25-08-81	0.6	20.5	7.8	385	8.7	--
	20-09-81	1	10.3	8.3	335	7.5	--
		108	5.3	1.3	1896	7.1	--
	08-11-81	1	0.5	9.2	440	7.7	+450
		50	2.5	5.9	405	7.2	+440
		60	--	--	377	--	+150
		65	--	--	23	--	+10
		70	--	--	442	--	-80
		75	--	--	430	--	-240
		85	3.0	2.8	1128	6.8	-40
		108	--	--	1977	--	-360
		108.5	3.2	2.9	2047	6.7	-70
		109	--	--	1907	--	-360
Outflow SP-1	24-08-81	--	3	12.8	1012	7.4	--
Outflow SP-2	24-08-81	--	17.5	8.2	140	7.8	--
Outflow SP-3	24-08-81	--	1.0	13.9	300	7.7	--
L. Athabasca	25-08-81	1*	16.8	9.5	85	--	--
		7*	15.0	9.6	90	--	--
		12*	13.0	9.4	100	--	--

*Water sample was a composite of water from these three depths.

TABLE 7.6.13: WATER QUALITY LABORATORY DATA FOR GUNNAR OPEN PIT, AUGUST TO NOVEMBER 1981

8 November 1981	Units	60 m	65 m	70 m	75 m	108 m	109 m
Total Uranium	ug/L	362	168	138	96	2500	2400
Dissolved Uranium	ug/L	360	88	53	27	2500	2400
Total Radium-226	Bq/L	0.13	0.30	0.35	0.45	1.0	1.2
Dissolved Radium-226	Bq/L	0.13	0.25	0.30	0.45	1.0	1.1

23-25 August 1981	Units	Outflow from 7 m depth	Inside Pit
Bicarbonate	mg/L	66	68
Calcium	mg/L	34	35
Chloride	mg/L	10	14
Magnesium	mg/L	10	13
Potassium	mg/L	3.0	3.0
Sodium	mg/L	6.1	6.2
Sulphate	mg/L	72	79
Total Alkalinity	mg/L	54	55
Total Inorganic Carbon	mg/L	13	12
Total Organic Carbon	mg/L	5	8
Total Dissolved Solids	mg/L	172	173
Total Suspended Solids	mg/L	2	2

TABLE 7.6.14: WATER QUALITY DATA AT DIFFERENT DEPTHS, GUNNAR OPEN PIT, 23 AUGUST 1981 AND 20 SEPTEMBER 1981

	Units	August 23, 1981				September 20, 1981	
		1 m	50 m	85 m	108 m	1 m	108 m
Bicarbonate	mg/L	70	68	190	251	68	251
Calcium	mg/L	34	36	128	208	35	187
Chloride	mg/L	10	10	59	73	10	75
Magnesium	mg/L	10	9	50	43	8	58
Potassium	mg/L	2.8	3.2	5.6	7.4	3.0	6.8
Sodium	mg/L	6.1	6.6	33	47	6.3	46
Sulphate	mg/L	74	80	288	511	75	456
Arsenic	ug/L	1.6	1.6	2.1	2.6	1.6	3.5
Cyanide	ug/L	<0.1	3.0	<0.1	<0.1	<0.1	<0.1
Mercury	ug/L	<0.05	0.92	<0.05	<0.05	<0.05	<0.05
Selenium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0018	0.0015	<0.0005	0.0040	0.0099	0.0007
Chromium	mg/L	0.008	0.008	0.006	0.009	0.009	0.006
Cobalt	mg/L	0.002	0.002	0.001	0.004	0.004	0.002
Copper	mg/L	0.003	0.004	0.004	0.005	0.004	0.002
Total Alkalinity	mg/L	57	56	156	206	56	206
Total Kjeldahl Nitrogen	mg/L	0.72	0.51	0.23	2.6	0.49	1.7
Ortho Phosphate	mg/L	0.58	1.2	0.17	0.80	0.80	0.12
Total Phosphate	mg/L	1.3	2.1	1.7	0.94	1.5	0.94
Total Inorganic Carbon	mg/L	15	15	39	50	15	58
Total Organic Carbon	mg/L	3	1	2	5	3	6
Total Dissolved Solids	mg/L	175	169	645	1050	168	1020
Total Suspended Solids	mg/L	2	2	2	2	2	2
Total Lead-210	Bq/L	0.12	<0.02	0.30	0.09*	0.05	0.45
Total Radium-226	Bq/L	0.09	0.06	0.12	0.40	0.14	0.35
Total Uranium	ug/L	708+/-89	320+/-19	437	2900	511+/-87	2800
Iron	mg/L	0.044	0.071	0.064	0.13	0.037	0.033
Lead	mg/L	0.018	0.016	<0.002	0.024	0.021	0.009
Manganese	mg/L	0.014	0.39	0.81	0.87	0.010	0.67
Nickel	mg/L	0.003	0.004	0.003	0.009	0.006	0.005
Zinc	mg/L	0.009	0.009	0.016	0.012	0.003	0.006
Aluminum	mg/L	0.12	0.087	1.3	0.41	0.10	<0.05
Barium	mg/L	0.061	0.036	0.11	0.030	0.039	0.049
Molybdenum	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Thorium-232	Bq/L	0.01	<0.01	---	0.01	0.03	0.01
Total Thorium-230	Bq/L	0.06	0.05	---	0.05	0.20	0.05
Total Thorium-228	Bq/L	<0.01	0.02	---	0.01	0.03	0.02
Total Thorium-227	Bq/L	<0.02	<0.02	---	<0.02	<0.02	<0.02

*Result questionable.

TABLE 7.6.15: WATER QUALITY DATA AT DIFFERENT DEPTHS, GUNNAR OPEN PIT, 08 NOVEMBER 1981

	Units	1 m	50 m	85 m	108.5 m
Bicarbonate	mg/L	81	74	189	310
Calcium	mg/L	37	36	97	196
Chloride	mg/L	6.4	10	39	72
Magnesium	mg/L	8	10	24	62
Potassium	mg/L	2.4	2.3	3.6	5.5
Sodium	mg/L	6.0	5.9	23	42
Sulphate	mg/L	66	66	192	481
Total Kjeldahl Nitrogen	mg/L	0.86	0.79	6.4	5.3
Ortho Phosphate	mg/L	1.7	1.1	2.6	0.06
Total Phosphate	mg/L	1.7	1.6	3.2	0.99
Total Inorganic Carbon	mg/L	10	10	39	53
Total Organic Carbon	mg/L	8	8	6	5
Total Dissolved Solids	mg/L	176	180	496	1060
Total Suspended Solids	mg/L	2	1	<1	<1
Total Lead-210	Bq/L	<0.02	0.07	0.30	0.30
Total Radium-226	Bq/L	0.13	0.16	1.2	1.2
Thorium	mg/L	0.044	0.048	0.073	0.21
Total Uranium	ug/L	382	362	262	2750
Arsenic	ug/L	1.6	1.5	2.5	3.0
Cyanide	ug/L	0.4	2.6	<0.1	<0.1
Mercury	ug/L	<0.05	<0.05	<0.05	<0.05
Selenium	mg/L	0.001	0.001	0.002	0.002
Cadmium	mg/L	<0.0005	<0.0005	<0.0005	0.0019
Chromium	mg/L	0.005	0.002	0.008	0.011
Cobalt	mg/L	0.001	0.002	<0.001	<0.001
Copper	mg/L	0.017	0.006	0.002	0.006
Iron	mg/L	0.10	0.061	0.086	0.12
Lead	mg/L	0.052	0.011	0.13	0.006
Manganese	mg/L	0.030	0.057	1.2	0.66
Nickel	mg/L	0.021	0.004	0.014	0.027
Zinc	mg/L	0.078	0.018	0.019	0.011
Aluminum	mg/L	0.59	0.56	1.4	1.8
Barium	mg/L	0.028	0.030	0.12	0.036
Molybdenum	mg/L	<0.005	<0.005	<0.005	<0.005
Total Alkalinity	mg/L	66	61	155	254
Specific Conductivity*	umho/cm	280	283	745	1340

*Measured in the SRC laboratory.

TABLE 7.6.16: RADIONUCLIDE CONTENT OF THREE PIKE FROM GUNNAR OPEN PIT, SEPTEMBER 1981 (Bq/g of ash except uranium in ug/g of ash)

	Flesh			Bone		
Lead-210	0.06	0.14	0.20	0.13	0.02	0.04
Radium-226	0.02	0.02	0.04	0.15	0.09	0.09
Uranium	2.3	1.3	1.7	15.1	8.5	6.0

TABLE 7.6.17: SEDIMENT QUALITY DATA, GUNNAR OPEN PIT, 24-25 AUGUST 1981

	Units	S-6 7 m	S-3 41.5 m	S-5 82 m	S-1 110 m
Total Kjeldahl Nitrogen	%	0.057	0.13	0.13	0.078
Total Phosphate	%	0.35	0.63	0.63	0.40
Total Carbon	%	NA*	NA*	NA*	NA*
Organic Carbon	%	NA*	NA*	NA*	NA*
Inorganic Carbon	%	2.22	2.28	2.04	6.59
Total Radium-226	Bq/g	1.5	4.0	4.0	5.5
Total Lead-210	Bq/g	3	17	20	21
Total Polonium-210	Bq/g	0.30	0.90	1.1	2.2
Total Thorium	ug/g	12	12	17	16
Water Soluble Sulphate	%	0.27	1.05	0.40	1.04
Moisture	%	84.0	98.7	97.6	98.7
Loss on Ignition	%	2.92	6.15	6.06	4.65
Colour		grey-black	grey-black	grey-black	grey-black
Odour		rotting org.	rotting org.	rotting org.	rotting org.
Texture		muddy	muddy	muddy	muddy
Arsenic	ug/g	2.7	6.1	5.8	6.7
Barium	ug/g	89	167	153	93
Cadmium	ug/g	0.92	<0.5	<0.5	13
Chromium	ug/g	20	18	20	19
Cobalt	ug/g	5.4	6.9	7.5	6.9
Copper	ug/g	16	28	27	30
Uranium	ug/g	636	2060	2460	7820
Iron	ug/g	13800	17700	17400	15000
Lead	ug/g	1.8	<2.0	<2.0	8.0
Manganese	ug/g	129	304	276	150
Mercury	ug/g	0.03	<0.5	<0.1	<0.5
Nickel	ug/g	44	20	21	26
Vanadium	ug/g	24	29	34	39
Zinc	ug/g	111	95	102	200

*NA = not available.

TABLE 7.6.18: WATER QUALITY OF SEEPAGE FROM THE GUNNAR SITE AND ONE SAMPLE FROM LAKE ATHABASCA, AUGUST 1981

		SP-1	SP-2	SP-3	Open Pit (1 m)	Lake Athabasca*
Bicarbonate	mg/L	[illegible]	24	100	81	14
Calcium	mg/L	90	10	40	37	8
Chloride	mg/L	14	5.2	10	6.4	4.2
Magnesium	mg/L	36	2	12	8	2
Potassium	mg/L	7.7	1.3	5.0	2.4	1.1
Sodium	mg/L	23	3.0	11	6.0	2.8
Sulphate	mg/L	330	8.3	75	66	9.3
Total Alkalinity	mg/L	72	20	82	66	11
Total Inorganic Carbon	mg/L	15	7	18	10	7
Total Organic Carbon	mg/L	5	3	7	8	2
Total Dissolved Solids	mg/L	547	51	737	176	44
Total Suspended Solids	mg/L	12	2	20	2	3
Total Kjeldahl Nitrogen	mg/L	0.52	0.44	0.49	0.86	0.39
Total Phosphate	mg/L	0.20	0.20	0.20	1.7	0.13
Total Lead-210	Bq/L	2.0	0.20	1.6	<0.02	<0.02
Total Radium-226	Bq/L	0.16	0.05	0.30	0.13	0.05
Uranium	ug/L	18,000	56	26,800	382	0.94
Arsenic	ug/L	0.8	<0.5	13	1.6	<0.5
Cyanide	ug/L	0.9	<0.1	<0.1	0.4	<0.1
Mercury	ug/L	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	mg/L	0.002	<0.001	0.005	0.001	<0.001
Cadmium	mg/L	0.002	<0.0005	0.002	<0.0005	0.002
Chromium	mg/L	0.008	0.008	0.009	0.005	0.004
Cobalt	mg/L	0.015	<0.001	0.018	0.001	0.002
Copper	mg/L	0.054	0.003	0.081	0.017	0.008
Iron	mg/L	0.65	0.13	0.74	0.10	0.057
Lead	mg/L	0.076	0.005	0.10	0.052	0.030
Manganese	mg/L	0.59	0.013	0.043	0.030	0.003
Nickel	mg/L	0.022	0.017	0.020	0.021	0.008
Zinc	mg/L	0.045	0.008	0.021	0.078	0.064
Aluminum	mg/L	1.7	0.25	1.8	0.59	0.28
Barium	mg/L	0.043	0.019	0.070	0.028	0.018
Molybdenum	mg/L	0.024	<0.005	0.022	<0.005	<0.005

*The Lake Athabasca sample was a composite sample containing equal aliquots of water from 1 m below the surface, 1 m above the bottom, and mid-depth. The sampling location was approximately 400 m south-southeast of the Gunnar wharf (in St. Mary's Channel).

TABLE 7.6.19: LITTORAL FAUNA COLLECTED AT THE GUNNAR OPEN PIT BY SWEEP NET, 25 AUGUST 1981

Organism	Number	Organism	Number
Hirudinea		Trichoptera	
Erpobdellidae		Phryganeidae	
Theromyzon sp.	6	*Agrypnia* sp.	8
Glossiphoniidae			
Glossiphonia sp.	131		
		Coleoptera	
		Haliplidae	
Hydracarina		*Haliplus* sp.	3
Limnocharidae		Dytiscidae	
Limnochares sp.	4	*Agabus* sp.	6
		Staphylinidae	
		Staphylimin	1
Cladocera			
Daphnidae			
Daphnia sp.	34	Diptera	
		Tipulidae	
		Tipula sp.	1
Copepoda		Dixidae	
Cyclopoida		*Dixella* sp.	2
Cyclops sp.	7	Chironomidae	
		Chironomus sp.	49
		Cricotopus sp.	36
Ostracoda	8		
		Tanytarsus sp.	15
		Heleidae	
Amphipoda		*Probezzia* sp.	2
Talitridae			
Hyalella azteca	14		
		Gastropoda	
		Lymnaeidae	
Collembola		*Lymnaea* sp.	1
Isotomidae		Planorbidae	
Isotoma sp.	2	*Gyraulus* sp.	1
Ephemeroptera			
Siphlonuridae			
Ameletus sp.	2		
Odonata			
Aeshnidae			
Aeshna sp.	14		

TABLE 7.6.20: NUMBERS OF BENTHIC INVERTEBRATES COLLECTED IN THE GUNNAR PIT BY EKMAN DREDGE, 24 AUGUST 1981 (number of individuals/522.5 cm^2 dredge sample)

Sample Depth (m)	1 110	2 109	3 41.5	4 82.5	5 7.0
Nematomorpha					
Gordioidea					
Gordius sp.	0	0	0	0	4
Diptera					
Chironomidae					
Chironomus sp.	0	0	5	0	682
Endochironomus sp.	0	0	1	0	0
Procladius sp.	0	0	3	0	0

TABLE 7.6.21: NUMBERS OF ZOOPLANKTON COLLECTED BY VERTICAL HAULS IN THE GUNNAR OPEN PIT, 23 AUGUST 1981

Sample Depth (m)	1 70	2* 15
Cladocera		
Daphnidae		
Daphnia sp.	6.3×10^2	5.9×10^2
Copepoda		
Cyclopoida		
Cyclops sp.	7.8×10^4	8.5×10^4

*Two oligochaetes and one corixid (*Sigara* sp.) were also collected in this vertical haul.

FIGURE 7.6.1: SAMPLING LOCATIONS, FLOODED GUNNAR OPEN PIT, 1981 (Tones, 1982)

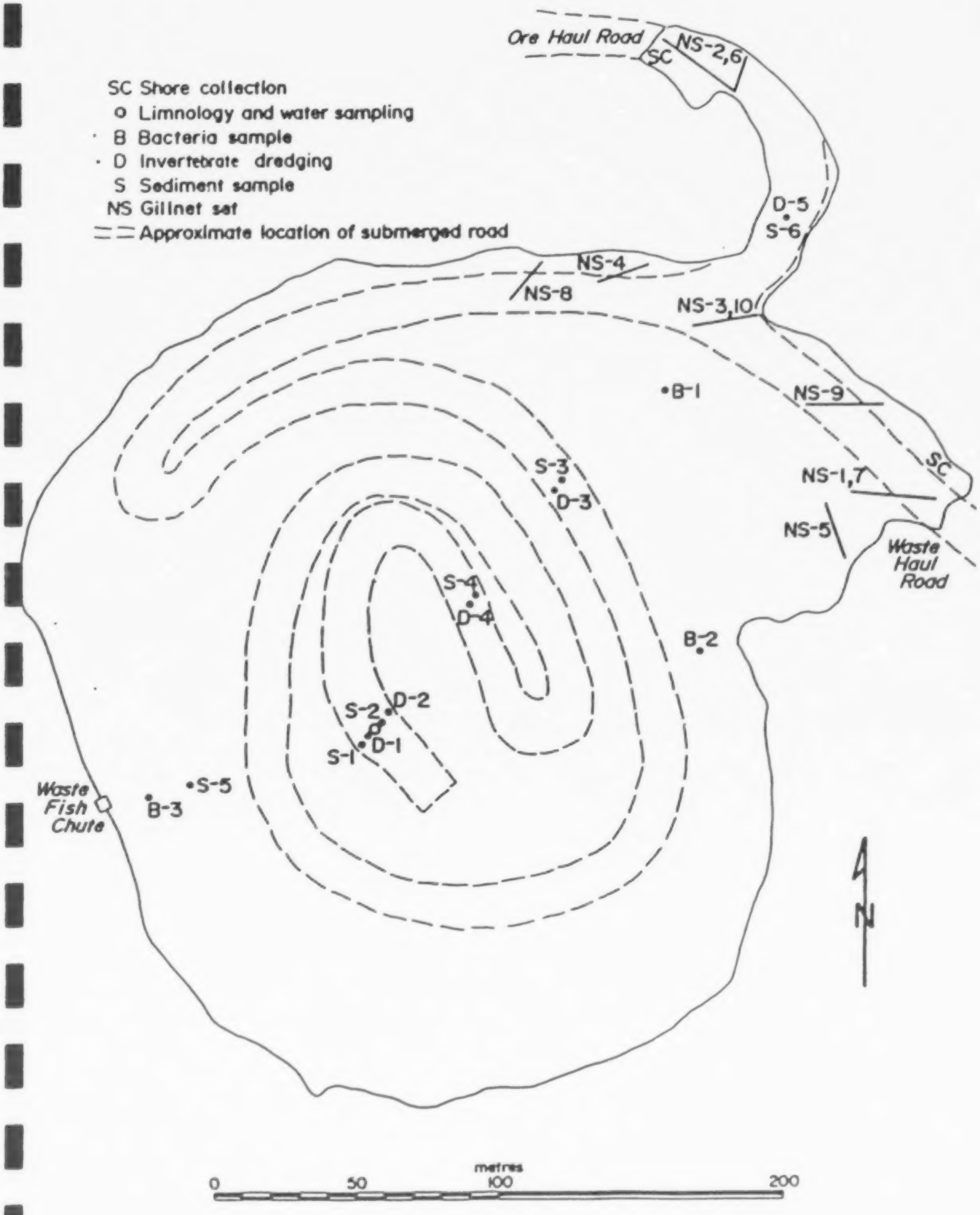
Ore Haul Road
SC
NS-2,6
SC Shore collection
o Limnology and water sampling
· B Bacteria sample
· D Invertebrate dredging
S Sediment sample
NS Gillnet set
Approximate location of submerged road
D-5
S-6
NS-4
NS-8
NS-3,10
B-1
NS-9
SC
S-3
D-3
NS-1,7
NS-5
Waste Haul Road
S-4
D-4
B-2
D-2
S-2
D-1
S-1
Waste Fish Chute
B-3
S-5
N
metres
0
50
100
200

TABLE 7.6.22: WATER QUALITY DATA FOR FREDETTE LAKE AND FREDETTE CREEK, JUNE 1981

	Unit	Fredette Lake Station #1 13-6-81	Fredette Lake Station #2 13-6-81	Fredette Creek Black Fly Riffle 19-6-81
Bicarbonate	mg/L	44	44	43
Calcium	mg/L	14	13	13
Chloride	mg/L	2.2	1.8	1.8
Magnesium	mg/L	2	3	3
Potassium	mg/L	1	1	1
Sodium	mg/L	2	2	2
Sulphate	mg/L	4.3	4.0	4.4
Arsenic	ug/L	<0.5	<0.5	<0.5
Cyanide	µg/L	1.6	0.4	4.0
Mercury	µg/L	<0.05	<0.05	<0.05
Selenium	mg/L	<0.001	<0.001	<0.001
Cadmium	mg/L	<0.0005	<0.0005	<0.0005
Chromium	mg/L	<0.001	<0.001	0.001
Cobalt	mg/L	<0.001	<0.001	<0.001
Copper	mg/L	0.060	0.028	0.022
Total Alkalinity	mg/L	36	36	35
Total Kjeldahl Nitrogen	mg/L	0.28	0.25	0.36
Ortho Phosphate	mg/L	<0.02	<0.02	<0.02
Total Phosphate	mg/L	0.20	0.20	0.17
Total Inorganic Carbon	mg/L	10	10	10
Total Organic Carbon	mg/L	9	8	4
Total Dissolved Solids	mg/L	120	111	107
Total Suspended Solids	mg/L	<1	<1	<1
Iron	mg/L	0.052	0.014	0.092
Lead	mg/L	<0.002	0.005	<0.002
Manganese	mg/L	0.011	0.004	0.013
Nickel	mg/L	<0.001	0.001	0.003
Zinc	mg/L	0.015	0.006	0.008
Aluminum	mg/L	0.21	0.064	0.30
Barium	mg/L	0.034	0.011	0.032
Molybdenum	mg/L	<0.005	<0.005	<0.005
Total Lead-210	Bq/L	0.02	0.03	0.70
Total Radium-226	Bq/L	<0.005	0.05	0.02
Total Uranium	ug/L	2.40	2.06	2.30

TABLE 7.6.23: WATER QUALITY DATA FOR FREDETTE LAKE, SEPTEMBER 1981

		September 12/81	
	Unit	Fredette Lake Station #1	Fredette Lake Station #2
Carbonate	mg/L	0	0
Chloride	mg/L	1.5	1.5
Bicarbonate	mg/L	48	46
Hydroxide	mg/L	0	0
Sulphate	mg/L	4.5	6
Total Inorganic Carbon	mg/L	6	4
Total Organic Carbon	mg/L	14	16
Total Kjeldahl Nitrogen	mg/L	0.58	0.49
Ortho Phosphate	mg/L	<0.02	<0.02
Total Phosphate	mg/L	0.18	0.20
Boron	mg/L	<0.01	<0.01
Cyanide	mg/L	<0.1	<0.1
Selenium	mg/L	<0.001	0.002
Silver	mg/L	<0.001	<0.001
Arsenic	mg/L	<0.5	<0.5
Barium	mg/L	0.075	0.025
Beryllium	mg/L	<0.001	<0.001
Calcium	mg/L	14	13
Cadmium	mg/L	<0.0005	<0.0005
Cobalt	mg/L	<0.001	<0.001
Chromium	mg/L	0.004	0.003
Copper	mg/L	0.002	0.002
Iron	mg/L	0.16	0.034
Potassium	mg/L	0.6	0.6
Magnesium	mg/L	2.5	2.3
Manganese	mg/L	0.071	0.012
Molybdenum	mg/L	0.002	0.002
Sodium	mg/L	1.5	1.4
Lead	mg/L	0.012	0.008
Silicone	mg/L	0.85	0.80
Tin (Sn)	mg/L	1.4	0.35
Titanium	mg/L	<0.001	<0.001
Vanadium	mg/L	<0.01	<0.01
Tungsten	mg/L	<0.01	<0.01
Zinc	mg/L	0.008	0.004
Total Lead-210	Bq/L	<0.02	0.02
Dissolved Radium-226	Bq/L	<0.005	<0.005
Total Radium-226	Bq/L	<0.005	<0.005
Uranium	µg/L	<0.5	8.0
Total Dissolved Solids	mg/L	71	65

TABLE 7.6.24: SEDIMENT RADIONUCLIDE DATA, PER GRAM DRY WEIGHT, JUNE 1981

Location	Date	Pb -210 (Bq/g)	Ra -226 (Bq/g)	Total U (μg/g)	Moisture (%)	Solids (%)
Fredette Creek	26-6-81	0.02	0.02	3.3	37.1	62.9
	26-6-81	<0.02	0.03	2.0	27.0	73.0
	26-6-81	<0.02	0.04	2.9	59.9	40.1
	23-6-81	0.02	0.03	3.4	49.9	50.1
	23-6-81	0.02	0.03	2.8	32.3	67.7
	23-6-81	0.03	0.03	4.0	64.0	36.0

TABLE 7.6.27: CONCENTRATION FACTORS FOR LARGE FISH SPECIES AND INSECTS

Location	Species	Radionuclide	Fish Concentration Factor[1] (water)					
			Skin	Flesh	Bone	Stomach	Liver	Gonads
Fredette Lake[2]	Lake Whitefish	Pb-210	100	25	350	12,500	1,500	1,000
		Ra-226	160	80	800	6,000	1,200	1,200
		U	78	3.3	343	5,625	234	131

Location	Species	Insect Concentration Factor (water and sediment)					
		Pb-210		Ra-226		U	
		Water	Sediment	Water	Sediment	Water	Sediment
Fredette Creek	Blackfly	57	2.0	455	0.45	317	0.32
	Dragonfly	49	1.5	300	0.30	522	0.52

---

[1] Polonium-210 C.F.'s could not be calculated because Po-210 was not determined in water samples.

[2] All concentration factors for Milliken and Fredette Lakes are estimates because many of the data points were less than detection limits.

TABLE 7.6.25: TOTAL MEAN RADIONUCLIDE CONTENT OF LARGE FISH SPECIES (standard deviation in parentheses)

			Mean								
			Skin		Flesh		Bone		Stomach[1]	Liver[1]	Gonad[1]
Location	Species	Radio-nuclide	ash	wet	ash	wet	ash	wet	wet	wet	wet
Fredette Lake	Lake Whitefish	Pb -210	0.03	0.002	0.03	0.0005	0.03	0.007	0.2	0.02	0.02
		(Bq/g)	(0.02)	(0.001)	(0.02)	(0.0007)	(0.01)	(0.004)	(0.30)	(0.01)	(0.00)
		Ra -226	0.02	0.0008	0.01	0.0004	0.01	0.004	0.03	0.01	0.01
		(Bq/g)	(0.01)	(0.0006)	(0.02)	(0.0009)	(0.02)	(0.005)	(0.03)	(0.002)	(0.002)
		U	4.39	0.25	1.09	0.01	4.11	1.10	18.0	0.75	0.42
		(ug/g)	(5.56)	(0.33)	(1.27)	(0.01)	(6.31)	(1.74)	(20.8)	(1.26)	(0.62)
		Po -210[2]	--	--	--	--	--	--	0.25	0.03	0.02
		(Bq/g)	--	--	--	--	--	--	(0.28)	(0.05)	(0.02)

[1] Samples were wet ashed, therefore no dry ash results.

[2] Polonium -210 determinations were done only on internal organs.

Note: Other fish species in Fredette Lake include lake trout and northern pike.

TABLE 7.6.26: RADIONUCLIDE CONTENT OF INSECT SAMPLES COLLECTED IN JUNE 1981

Location	Species	Dry Weight g	Wet Weight g	Pb -210 total		Ra -226 total		U total	
				Bq/g dry	Bq/g wet	Bq/g dry	Bq/g wet	µg/g dry	µg/g wet
Fredette Creek	Blackfly larvae	0.9107	8.3213	0.19	0.020	0.02	0.002	2.9	0.317
		7.4397	29.0708	0.04	0.010	0.02	0.005	4.7	1.202
		2.1883	13.5426	0.03	0.004	0.07	0.011	4.0	0.646
		2.2936	15.8403	0.08	0.011	0.06	0.008	4.4	0.637
		1.7820	11.8609	0.25	0.037	0.09	0.013	4.4	0.661
		1.1564	7.9199	0.07	0.010	0.07	0.010	8.3	1.211
		0.9809	7.4469	0.18	0.023	0.20	0.026	6.4	0.843
		0.7114	8.7336	0.19	0.015	0.08	0.006	6.8	0.553
		0.9635	9.4004	0.18	0.018	0.11	0.011	5.4	0.553
		0.8343	7.5899	0.18	0.019	0.05	0.005	7.6	0.835
		0.9602	8.0661	0.25	0.029	0.08	0.009	3.3	0.392
		0.6818	8.6000	0.25	0.019	0.13	0.010	15	1.189
		1.1989	8.0020	0.55	0.082	0.10	0.014	5.8	0.868
		0.9484	8.3767	0.35	0.396	0.05	0.005	4.4	0.498
		3.2043	16.9987	0.20	0.037	0.02	0.003	2.6	0.490
		2.7647	13.5740	0.05	0.010	0.02	0.004	4.4	0.896
		3.2841	19.1066	0.05	0.008	0.02	0.003	3.2	0.550
Fredette Creek	Dragonfly nymphs	0.4269	2.2244	0.14	0.026	0.01	0.001	12	2.303
		1.5734	5.6778	0.15	0.041	0.04	0.011	0.38	0.105

TABLE 7.6.28: ESTIMATED DOSE RATES TO FISH IN FREDETTE LAKE

External Dose Rate to Lake Whitefish		Radiation		Radiation
		From Ra-226[1]	From Po-210	From Pb-210[2]
Bone	urad/hr	6.7		0.70
	mrad/yr	58.6		6.1
Gonad	urad/hr	9.8	6.1	1.4
	mrad/yr	85.8	53.4	12.3
Liver	urad/hr	9.8	8.2	1.4
	mrad/yr	85.8	71.8	12.3
Skin	urad/hr	1.8		0.14
	mrad/yr	15.8		1.2
Flesh	urad/hr	0.61		0.03
	mrad/yr	5.3		0.26
TOTAL	urad/hr	28.7	14.3	3.7
	mrad/yr	251	125	32.1

Internal Dose Equivalent from Ra-226, Po-210 and Pb-210[3]	Lake Whitefish		White Suckers	
	Overall Tissues Analyzed rems/yr	Gonads Only rems/yr	Overall Tissues Analyzed rems/yr	Gonads Only rems/yr
Fredette Lake	7.6	2.8	-	-

[1] Includes dose from radon daughters.

[2] Includes dose from Bi-210 (daughter of Pb-210).

[3] Assuming ICRP #26 (1977) quality factors of 20 for alpha and 1 for beta.

TABLE 7.6.29: LEAD-210 LEVELS (Bq/g ash, Bq/g wet weight) IN LAKE WHITEFISH FROM FREDETTE LAKE

SAMPLING DATE	SKIN		FLESH		BONE		STOMACH	LIVER	GONAD
	ASH	WET	ASH	WET	ASH	WET	WET	WET	WET
29-6-81	0.04	0.0018	<0.02	<0.0002	0.03	0.0078	-	0.02	<0.02
15-9-81	0.04	0.0025	0.05	>0.0006	0.03	0.0080	0.20	<0.02	<0.02
15-9-81	0.50*	-	0.04	0.0005	0.03	0.0111	0.08	<0.02	-
15-9-81	0.35*	-	0.02	0.0002	0.12*	-	-	-	-
14-9-81	0.04	0.0017	0.07	0.0008	<0.02	0.0050	-	0.06	-
14-9-81	0.25*	-	0.16*	-	0.03	0.0072	-	<0.02	-
15-9-81	0.03	0.0023	0.03	0.0003	0.02	0.0050	0.08	<0.02	<0.02
15-9-81	<0.02	0.0010	0.20*	-	0.05	0.0125	-	<0.02	<0.02
14-9-81	<0.02	<0.0009	0.03	0.0029	0.03	0.0082	<0.02	<0.02	-
14-9-81	<0.02	<0.0011	<0.02	<0.0014	0.03	0.0089	0.30	<0.02	-
1-7-81	0.10	0.0055	<0.02	<0.0001	<0.02	<0.0056	0.13	<0.02	<0.02
15-9-81	<0.02	0.0012	<0.02	<0.0002	0.04	0.0169	0.04	<0.02	-
15-9-81	<0.02	<0.0009	0.02	0.0002	<0.02	<0.0050	<0.02	<0.02	-
29-6-81	0.03	0.0015	<0.02	<0.0002	<0.02	<0.0057	1.1	<0.02	<0.02
2-7-81	<0.02	<0.0011	0.04	0.0004	<0.005	<0.0008	0.11	<0.02	<0.02
30-6-81	0.08	0.0037	<0.02	0.0002	<0.02	<0.0041	0.20	-	<0.02
15-9-81	<0.02	<0.0007	0.02	0.0002	0.02	0.0045	0.11	<0.02	-
14-9-81	0.03	0.0017	<0.02	<0.0002	0.03	0.0083	-	<0.02	<0.02
2-7-81	-	-	<0.02	<0.0002	-	-	-	-	<0.02
15-9-81	0.02	0.0001	0.08	0.0007	0.04	0.0088	-	<0.02	-
2-7-81	0.04	0.0014	<0.02	<0.0002	-	-	-	-	-

*result appears too high, yet insufficient ash to redo the analysis

TABLE 7.6.30: RADIUM-226 LEVELS (Bq/g ash, Bq/g wet weight) IN LAKE WHITEFISH FROM FREDETTE LAKE

SAMPLING DATE	SKIN		FLESH		BONE		STOMACH	LIVER	GONAD
	ASH	WET	ASH	WET	ASH	WET	WET	WET	WET
29-6-81	.02	0.0009	0.01	0.0001	0.01	0.0026	-	0.01	0.01
15-9-81	0.03	0.0019	<0.005	>0.0006	0.08	0.0214	0.16*	0.01	<0.005
15-9-81	0.02	0.0008	<0.005	<0.0001	0.01	0.0089	0.40*	<0.005	-
15-9-81	0.03	0.0015	0.07	0.0007	<0.005	<0.0013	-	-	-
14-9-81	0.04	0.0019	0.02	0.0002	0.01	0.0025	-	<0.005	-
14-9-81	0.01	0.0006	<0.005	<0.0001	<0.005	<0.0012	-	0.01	-
15-9-81	0.02	0.0015	0.01	0.0001	0.02	0.0050	0.02	<0.005	<0.005
15-9-81	0.01	0.0006	0.01	0.0001	0.03	0.0075	-	<0.005	0.01
14-9-81	<0.005	<0.0009	<0.005	<0.0001	<0.005	<0.0014	<0.005	<0.005	-
14-9-81	0.01	0.0006	0.06	0.0040	<0.005	<0.0015	0.06	<0.005	-
1-7-81	0.02	0.0011	<0.005	0	0.02	0.0056	0.09	<0.005	<0.005
15-9-81	<0.005	<0.0003	<0.005	<0.0001	<0.005	<0.0015	0.01	<0.005	-
15-9-81	<0.005	<0.0002	<0.005	0	<0.005	<0.0013	0.03	<0.005	-
29-6-81	0.02	0.0010	0.75*	-	0.01	0.0028	0.02	<0.005	<0.005
2-7-81	<0.005	<0.0003	0.12*	0.0013*	0.01	0.0016	0.02	<0.005	<0.005
30-6-81	<0.005	<0.0002	<0.005	<0.0001	<0.005	<0.0010	0.02	-	<0.005
15-9-81	0.04	0.0015	<0.005	<0.0001	<0.005	<0.0011	0.01	<0.005	-
14-9-81	0.01	0.0006	<0.005	<0.0001	-	-	-	<0.005	<0.005
2-7-81	-	-	<0.005	0	<0.005	<0.0013	-	-	<0.005
15-9-81	<0.005	<0.0002	1.1*	0.0091*	<0.005	<0.0011	-	<0.005	-
2-7-81	<0.005	<0.0002	<0.005	<0.0001	<0.005	<0.0015	-	-	-

* result appears too high to be correct

TABLE 7.6.31: URANIUM LEVELS (ug/g ash, ug/g wet weight) IN LAKE WHITEFISH FROM FREDETTE LAKE

SAMPLING DATE	SKIN		FLESH		BONE		STOMACH	LIVER	GONAD
	ASH	WET	ASH	WET	ASH	WET	WET	WET	WET
29-6-81	0.80	0.0352	4.90	0.0468	1.0	0.2605	-	1.1	2.1
15-9-81	13.2	0.8120	1.10	0.0126	15.3	4.0901	6.1	1.2	0.13
15-9-81	2.2	0.0853	0.40	0.0046	0.9	0.5556	1.6	0.31	-
15-9-81	0.3	0.0148	<0.02	<0.0002	0.3	0.0750	-	-	-
14-9-81	0.2	0.0096	<0.02	<0.0002	0.4	0.0993	-	0.40	-
14-9-81	1.1	0.0613	0.40	0.0046	0.3	0.0716	-	0.07	-
15-9-81	9.6	0.7357	0.90	0.0102	10.2	2.5563	18.2	0.39	0.09
15-9-81	3.0	0.1664	0.30	0.0029	4.0	1.000	-	0.07	0.70
14-9-81	1.2								
		0.0528	<0.20	<0.0020	0.7	0.1922	94*	0.11	-
14-9-81	0.6								
		0.0335	0.90	0.0102	1.0	0.2977	9.0	0.089	-
1-7-81	14.0	0.7683	2.50	0.0176	22	6.1635	47	5.2	0.30
15-9-81									
	0.1	0.0698	0.80	0.0074	1.0	0.2922	18	0.090	-
15-9-81	<0.5								
		<0.0223	<0.2	<0.0017	0.4	0.1000	13	0.14	-
29-6-81	9.6								
		0.4837	3.2	0.0255	11	3.1087	6.4	0.45	0.12
2-7-81	18	0.9954	2.8	0.0294	4.0	0.6193	68	1.8	0.16
30-6-81	2.6								
		0.1203	0.4	0.0037	0.4	0.0819	8.8	-	<0.1
15-9-81	<0.2	<0.0074	<0.2	<0.0002	0.5	0.1130	2.3	<0.1	-
14-9-81	8.2								
		0.4718	1.9	0.0191	-	-	-	1.2	0.13
2-7-81	-	-	0.7	0.0069	-	-	-		0.4
15-9-81	0.8								
		0.0289	0.6	0.0050	0.5	0.1103	-	0.08	-
2-7-81	0.4								
		0.0143	0.5	0.0047	-	-	-	-	-

* result appears too high to be correct

TABLE 7.6.32: POLONIUM-210 LEVELS (Bq/g wet weight) IN LAKE WHITEFISH FROM FREDETTE LAKE

SAMPLING DATE	STOMACH	LIVER	GONAD
14-9-81	-	0.07	-
15-9-81	2.00	0.20	0.04
14-9-81	-	0.01	-
29-8-81	0.40	0.07	-
15-9-81	0.10	0.04	0.01
15-9-81	-	0.01	0.9*
29-5-81	-**	-	-
29-6-81	-	0.01	0.01
1-7-81	-	<0.005	<0.005
29-6-81	1.20	<0.005	<0.005
14-9-81	0.03	<0.005	-
15-9-81	0.07	<0.005	-
14-9-81	0.50	0.01	-
15-9-81	0.90	<0.005	-
1-7-81	0.06	-	-
2-7-81	0.05	<0.005	<0.005
30-6-81	0.35	-	0.01
15-9-81	0.11	<0.005	-
14-9-81	-	0.11	<0.005
2-7-81	-	-	0.01
15-9-81	-	0.01	-

* result appears too high to be correct

** insufficient sample to do analysis

7.6.2 Vegetation

TABLE 7.6.33: VASCULAR PLANTS IDENTIFIED ON GUNNAR TAILINGS AREAS

	GUNNAR MAIN	GUNNAR CENTRAL	LANGLEY BAY
GRAMINEAE			
Agrostis hyemalis (Walt.) BSP	-	-	X
Agropyron trachucaulon (Link) Malte. [var. *unilaterale* (Cassidy)]	X	-	-
Beckmannia syzigachine (Steud.) Fern.	-	-	X
Calamagrostis canadensis (Michx.)Beauv.	X	X	X
Calamagrostis inexpansa Gray	X	X	X
Puccinellia distans (L.) Parl.	X	X	X
Hordeum jubatum L.	X	-	-
Deschampsia cespitosa (L.) Beauv.	-	-	X
JUNCACEAE			
Juncus alpinus Vill.	X	-	-
Juncus balticus Willd.	X	-	-
Juncus bufonius L.	X	-	-
JUNCAGINACEAE			
Triglochin palustris L.	X	-	-
LABIATAE			
Mentha arvensis L. [var. *villosa* (Benth.) S.R. Stew.]	X	-	-
ONAGRACEAE			
Epilobium angustifolium L.	X	-	-
ORCHIDACEAE			
Spiranthes Romanzoffiana Cham.	X	-	-

TABLE 7.6.33: VASCULAR PLANTS IDENTIFIED ON GUNNAR TAILINGS AREAS

	GUNNAR MAIN	GUNNAR CENTRAL	LANGLEY BAY
PLANTAGINACEAE			
Plantago major L.	X	-	-
POLYGONACEAE			
Rumex occidentalis Wats.	X	-	-
Rumex mexicans Meisr.	-	-	X
Polygonum aviculare L.	-	-	X
ROSACEAE			
Rosa acicularis Linde.	X	-	-
Potentilla norvegica L.	X	-	-
RANUNCULACEAE			
Ranunculus filiformis Michx. [var. *flammula* (L.)]	-	-	X
SAXIFRAGACEAE			
Parnassia palustris L.	X	-	-
SALICAEAE			
Salix glauca L.	X	-	-
Salix Bebbiana Sarg.	X	-	-
Salix interior Rowlee	X	-	-
Populus tremuloides Michx.	X	-	-
Populus balsamifera L.	X	-	-
TYPHACEAE			
Typha spp.	X	-	-

TABLE 7.6.34: PLANTS NATURALLY COLONIZING ON THE GUNNAR URANIUM MILL TAILINGS

THE MAIN TAILINGS AREA (Mudford Lake Site)

On dry, open, loose, sandy, upper substrate:

Puccinellia nuttalliana (ff, d)
Hordeum jubatum (ff, d)
Puccinellia distans-interior (ff)
Agropyron trachycaulum
  var. unilaterale (o)
Equisetum hiemale (o, lf)
Equisetum arvense (o, lff)
Hieracium umbellatum (vo, lf)
Erigeron acris var. asteroides (vo)
Chenopodium album (r)

On mesic-moist, tighter, semi-vegetated, salt-encrusted substrate:

Puccinellia nuttalliana (ff-f)
Hordeum jubatum (ff-f)
Equisetum arvense (ff, lf)
Achillea borealis (o, lff)
Epilobium angustifolium (o, lff)
Hieracium umbellatum (o, lff)
Taraxacum officinale (o, lf)
Solidago spathulata
  var. neomexicana (o)
Erigeron acris
  var. asteroides (vo)
Salix glauca (o, lf)
Salix arbusculoides (o, lf)
Populus tremuloides (vo, lf)
Aster ciliolatus (vo)
Erigeron lonchophyllus (vo)

Near SW edge bordering green alder-willow-white birch-white spruce wooded ridges:

Alnus crispa (ff)
Betula neoalaskana (ff)
Puccinellia nuttalliana (ff)
Salix glauca (ff, lc)
Salix discolor (o, lf)
Picea glauca (o)
Parnassia palustris (o, lff)
Rumex occidentalis (o)
Shepherdia canadensis (vo)

On mes-moist borders of black spruce woods and drowned-out black spruce island:

Betula neoalaskana (ff, lf)
Alnus crispa (ff)
Salix arbusculoides (ff)
Erigeron acris var. asteroides (ff)
Calamagrostis canadensis (ff)
Salix bebbiana (ff)
Picea mariana (ff)
Equisetum arvense (ff)
Calamagrostis inexpansa (o-ff)
Agrostis scabra (o, lff)
Agropyron trachycaulum
  var. trachycaulum (o)
Populus balsamifera (o)
Shepherdia candensis (vo)
Aster brachyactis (o, lf)
Salix interior (vo, lc)
Ledum groenlandicum (vo)

On moist-wet lower mud-flats and drainages

Puccinellia nuttalliana (ff)
Triglochin palustris (ff, la)
Juncus bufonius (ff, la)
Aster brachyactis (ff, lf)
Juncus alpinus (ff, la)
Rumex occidentalis (ff, lf)
Salix bebbiana (ff, lf)
Juncus balticus (o, lc)
Calamagrostis canadensis (o, lf)
Agrostis scabra (o, lff)
Epilobium watsonii (o)
Parnassia palustris (o)
Glyceria sp. (seedlings) (o, lc)
Carex aquatilis (o)
Salix interior (o, lc)
Calamagrostis inexpansa (o)
Agropyron trachycaulum
  var. trachycaulum (o)
Rorippa islandica (vo, lc) (seedlings)
Spiranthes romanzoffiana (vo, lf)
Plantago major (vo)
Habenaria hyperborea (vo)

d=dominant, a=abundant, c=common, f=frequent,
o=occasional, r=rare.
prefix: v=very, f=fairly, l=locally.

TABLE 7.6.34: PLANTS NATURALLY COLONIZING ON THE GUNNAR URANIUM MILL TAILINGS

Aquatics in ponds and edges:

Typha latifolia (ff, la & d)
Eleocharis palustris (ff, la)
Carex aquatilis (f, ld)
Scirpus cyperinus (ff)
Eleocharis acicularis (o, la)
Eleocharis quinqueflora (o, la)
Scirpus validus (o, lc)
Carex rostrata (o, lc)
Sparganium minimum (o)

LANGLEY BAY TAILINGS AREA

On moist-wet silty beach flats:

Deschampsia caespitosa (f, la & d)
Puccinellia nuttalliana (f, lc & d)
Glyceria borealis (f, lc)
Puccinellia distans-interior (f, lc)
Hordeum jubatum (f)
Carex aquatilis(ff)
Agrostis scabra (ff, lf)
Calamagrostis neglecta (ff)
Deschampsia mackenzieana (ff)
Carex viridula (ff, lf)
Carex crawfordii (ff, lf)
Eleocharis acicularis (ff, la)
Eleocharis palustris (ff, lc)
Juncus alpinus (ff)
Sagina nodosa ssp. borealis (ff, lf)
Polygonum aviculare (ff, lc)
Ranunculus flammula
  var. filiformis (ff, la)
Equisetum arvense (ff)
Ranunculus sceleratus (ff, lc)
Galium trifidum (o, la)
Carex lenticularis (o)
Calamagrostis canadensis (o, lf)
Parnassia palustris (o, lf)
Potentilla norvegica (o, lc)
Mentha arvensis (o, lc)
Rorippa islandica var fernaldii (o)
Polygonum lapathifolium
  var. salicifolium (o)
Epilobium adenocaulon (o)
Rumex salicifolius (o)
Beckmannia syzigachne (o, la)
Poa glauca (o)
Carex rostrata (o, la)
Juncus bufonius (o, la)
Salix bebbiana (o, lf)
Salix discolor (o)
Salix scouleriana (o)
Senecio congestus var. palustris (o)
Carex atherodes (vo, lc)

Aquatic plants in central creek:

Eleocharis palustris (ff, la)
Potamogeton filiformis (ff, la)
Potamogeton richardsonii (ff, lc)
Ranunculus aquatilis
  var. capillaceus (ff, lc)
Carex aquatilis (ff)
Potamogeton pusillus (o, lc)
Potamogeton alpinus
  var. tenuifolius (o, lf)
Sparganium multipedunculatum (o, lf)
Eleocharis acicularis (o, la)

On mesic-moist sandy flats:

Puccinellia nuttalliana (ff)
Hordeum jubatum (ff)
Calamagrostis canadensis (ff, lf & d)
Carex aquatilis (ff)
Agrostis scabra (ff)
Polygonum aviculare (ff, lc)
Parnassia palustris (o)
Potentilla norvegica (o)

On mesic-moist edges bordering alder-willow-aspen-black spruce woods

Calamagrostis canadensis (ff, lf)
Carex aquatilis (ff, lf)
Puccinellia nuttalliana (ff)
Calamagrostis inexpansa (ff, lf)
Alnus crispa (ff)
Betula neoalaskana (ff)
Picea mariana (ff)
Salix bebbiana (o)
Salix arbusculaides (o)
Salix glauca (o)
Agropyron trachycaulum
  var. trachycaulum (o)

TABLE 7.6.34: PLANTS NATURALLY COLONIZING ON THE GUNNAR URANIUM MILL TAILINGS

On mesic-moist edges bordering alder-willow-aspen-black spruce woods (Cont'd)

Hordeum jubatum (o, lf)
Equisetum palustre(o, lf)
Alnus rugosa (o)
Agrostis scabra (o)
Scirpus cyperinus (o)
Populus tremuloides (vo)
Galium boreale (o)
Equisetum sylvaticum (vo)
Calamagrostis lapponica (vo)
Spiranthes romanzoffiana (vo)
Castilleja raupii (vo)
Rhinanthus crista-galli (vo, lf)

Aquatic plants in small ponds:

Typha latifolia (f, la & d)
Scirpus validus (ff)
Myriophyllum exalbescens (ff)
Carex aquatilis (ff, lc)
Ranunculus aquatilis (ff, lc)
Potamogeton filiformis (ff, la)
Potamogeton pusillus (o, lf)
Sparganium multipedunculatum (o, lf)
Potamogeton foliosus (lf)

On moist-wet mud-flats:

Deschampsia caespitosa (f & d)
Puccinellia nuttalliana (f & d)
Agrostis scabra (f)
Juncus bufonius (f, la & d)
Hordeum jubatum (ff)
Rumex salicifolius (ff)
Triglochin palustris (o, lc)
Ranunculus sceleratus (o, lf)
Carex crawfordii (o)
Equisetum scirpoides (o, lf)

THE CENTRAL TAILINGS AREA

On mesic-moist black spruce and green alder-willow shrub borders.

Picea mariana (ff)
Betula neoalaskana (ff)
Alnus crispa (ff)
Calamagrostis inexpansa (ff)
Puccinellia nuttalliana (ff)
Agrostis scabra (ff)
Agropyron trachycaulum
  var. trachycaulum (o)
Habenaria hyperborea (vo)

On open, dry, loose tailings:

Puccinellia nuttalliana (ff)
Hordeum jubatum (ff)
Agropyron trachycaulum
  var. unilaterale (vo)

On moist mud-flats along drainages.

Carex aquatilis (ff, lc)
Calamagrostis inexpansa (ff, lc & d)
Puccinellia nuttalliana (ff, lf)
Agrostis scabra (ff, lf)
Triglochin palustris (ff, la & d)
Calamagrostis canadensis (ff)
Juncus alpinus (ff, lf)
Juncus bufonius (o, la)
Equisetum arvense (o)
Scirpus cyperinus (o)
Arenaria lateriflora (vo)
Habenaria hyperborea (vo)

TABLE 7.6.35: MOSS SPECIES OF THE CONTROL AREA (Kalin, 1981c)*

Sphagnum spp.
D. cf. aduncus
D. fluitans
Polytrichum juniperinum

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*As of the date of writing, identification of the moss samples sent to Dr. Beckett has not been received.

7.6.3 Soils and Associated Vegetation Analyses

TABLE 7.6.36: CHEMICAL ANALYSES OF TAILINGS FROM THE GUNNAR AREA

Tailings Area	Site Number	Depth cm	Available Nutrients* µg/g soil			
			NO_3-N	P	K	SO_4-S
Gunnar Main	2A	0-10	1	1	15	750
	2B	25-35	1	1	15	700
	4A	0-10	1	1	20	700
	4B	25-35	1	1	15	700
Gunnar Central	5A	0-10	1	1	25	1800
Langley Bay	7A	0-10	1	1	30	1450

*SO_4-S extracted using .001M Calcium chloride

NO_3-N, P, K, extracted using .5M Sodium bicarbonate

TABLE 7.6.37: ANALYSES OF TAILINGS FROM THE GUNNAR AREA

Tailings Suction	Site Number	Sample depth (cm)	Field Moisture Content (%)	Ammonium Acetate Extractible (me/100g)				pH	Conductivity (mmhos cm^{-1})	Salinity Classification*	Water Soluble me/100g		
				Na$^+$	Ca^{++}	Mg^{++}	K$^+$				Ca	Mg	Na
Gunnar Main	1A	0-1 (crust)	20.2	-	-	-	-	5.95	6.10	Moderately saline	-	-	-
	2A	0-10	5.04	0.21	33.9	0.25	0.025	6.20	1.65	Non-saline	4.3(1.7)***	nd**	nd
	2B	25-35	4.47	-	-	-	-	6.20	1.60	Non-saline	-	-	-
	3A	0-10	3.98	0.06	19.0	0.08	0.012	6.25	1.60	Non-saline	5.3(2.1)	nd	nd
	3B	25-35	5.40	-	-	-	-	6.80	1.65	Non-saline	-	-	-
	4A	0-10	3.61	0.04	21.1	0.08	0.012	6.25	1.70	Non-saline	7.5(3.0)	nd	nd
	4B	25-35	5.26	-	-	-	-	6.90	1.75	Non-saline	-	-	-
Gunnar Central	5A	0-10	16.5	2.43	22.6	15.0	0.025	5.00	15.00	Strongly saline	4.5(1.8)	15.6(6.3)	0.25(0.1)
	6A	0-1 (crust)	31.0	-	-	-	-	4.80	8.00	Strongly saline	-	-	-
Langley Bay	7A	0-10	35.8	0.86	38.9	4.33	0.038	5.00	5.10	Moderately saline	8.0(3.2)	8.0(3.2)	0.17(0.07)
	8A	0-10	6.75	-	-	-	-	4.98	2.00	Slightly saline	-	-	-

*Based on Jackson (1958) Soil Chemical Analysis **nd = not detectable ***values in parenthesis are me/ℓ

TABLE 7.6.38: PARTICLE SIZE ANALYSES OF TAILINGS FROM THE GUNNAR AREA

Tailings Section	Site Number	Sample depth cm	Total Sand %	Very fine sand %	Silt %	Clay %
Gunnar Main	2A	0–10	88.2	5.1	9.7	2.1
	3A	0–10	92.0	7.9	6.2	1.8
	4A	0–10	90.0	10.2	8.0	2.0
Gunnar Central	5A	0–10	85.0	15.1	10.9	4.1
Langley Bay	7A	0–10	35.0	—	60.8	4.2

*Sand = 0.05–2 mm, very fine sand = 0.05–0.1 mm, silt = 0.002–0.05 mm, clay = <0.002 mm.

TABLE 7.6.39: CONCENTRATIONS OF RADIONUCLIDES AND NUTRIENTS IN *Hordeum jubatum*, *Puccinellia distans* AND ASSOCIATED TAILINGS

	Seeds		Stems and Leaves		Roots		Tailings n = 10	
	H. jubatum	*P. distans*	*H. jubatum*	*P. distans*	*H. jubatum*	*P. distans*	*H. jubatum*	*P. distans*
Pb (ug/g)	10±3.5	20±3.6	13±5.1	16±8.7	116±32	184±24	188±138	263±151
Pb-210 (pCi/g)	1.7±1.6	3.5±1.9	7.8±5.7	3.5±2.6	56±53	21.4±8.7	74.7±54	71.2±63
Ra-226 (pCi/g)	1.7±1.2	2.3±2.9	6.1±4.1	2.7±1.6	26.8±17.7	18±7.1	88.7±84	64±57
K (mg/g) (2-week leachate)							12.0±8.2	10.1±4.9
NO_3+NO_2 (mg/g) (10-min extract)							0.85±0.5	0.32±0.18

TABLE 7.6.40: CONCENTRATIONS OF ELEMENTS IN WATER COLLECTED FROM D. fluitans CONTROL SITES AND IN D. fluitans PLANT TISSUE

Sample Location and Description	Date	pH	Conductivity (umhos/cm)	Pb-210 (pCi/L)	Pb (mg/L)	Zn (mg/L)	U (mg/L)	Al (mg/L)	Mg (mg/L)	Mn (mg/L)	Na (mg/L)	Ra-226 (pCi/L)	Ca (mg/L)	Cl (mg/L)
Control Site of L. fluitans														
Across road - spring	06.09.81	3.2	2,750	0.37±0.31	nd	1.03	0.28	192	335	21	nd	0.67±0.34	317	9
Below road - slope	06.09.81	2.8	1,700	3.4±1.4	nd	2.74	0.04	41	58	3	10	nd	134	8
Centre of moss carpet	06.09.81	2.6	3,700	0.18±0.29	nd	0.47	0.18	89	344	13	nd	nd	400	9
Precipitate zone	06.09.81	2.7	1,800	0.95±0.45	nd	0.18	0.12	34	74	4	11	0.67±0.39	173	9
Discharge zone	06.09.81	2.5	4,150	0.39±0.32	nd	0.84	0.59	144	290	13	nd	0.67±0.34	327	5
2 m out in lake	06.09.81	6.8	170	nd	nd	0.38	-	-	-	-	-	nd	-	-
D. fluitans from Control Site	06.09.81	-	-	0.5±0.7	nd	10.0	14.0	-	353	-	-	0.7±1.1	101	-

nd = not detectable.

TABLE 7.6.41: CHEMICAL CHARACTERISTICS OF THE GUNNAR TAILINGS AREA

Gunnar	Loss on Ignition %	pH	Electrical Conductivity µmhos/cm	Pb µg/g	Zn µg/g
Hummock Origin: n = 5	1.1 ± 0.8	7.4 ± 0.2 (n = 20)	2105 ± 210 (n = 20)	142 ± 36	28 ± 5
Pits, vegetation free: n = 12	1.0 ± 0.8	7.0 ± 0.8	2760 ± 1730	220 ± 110	35 ± 11
Root regions of:					
H. jubatum n = 10	1.7 ± 1.6	7.2 ± 0.2 (n = 5)	4400 ± 1770	188 ± 138	34 ± 21
P. distans n = 10	1.6 ± 0.8	6.7 ± 0.8 (n = 5)	2230 ± 1010	282 ± 150	35 ± 10
Small Opening: n = 5	2.0 ± 0.7	5.5 ± 1.0 (n = 3)	6630 ± 3870 (n = 3)	188 ± 83	31 ± 8
Gunnar Central: n = 5	1.6 ± 0.3	5.1 ± 0.5	4870 ± 2320	165 ± 33	33 ± 4
Langely Bay: n = 4	2.2 ± 0.3	5.3 ± 0.4	3700 ± 620	238 ± 46	51 ± 9

TABLE 7.6.42: CHEMICAL ANALYSIS OF WATER TAKEN FROM MOSS COLLECTION SITES

Analyte	Control Lake
pH	2.6
Total diss. solids mg/ℓ	1410
Ca mg/ℓ	126
Mg mg/ℓ	73
K mg/ℓ	1.4
Na mg/ℓ	5.3
SO_4 mg/ℓ	1070
Cl mg/ℓ	17
PO_4 mg/ℓ	0.30
Ammonia N mg/ℓ	0.21
Ra-226 Bq/ℓ	0.07
Pb-210 Bq/ℓ	0.11
U, total mg/ℓ	105
Th, total µg/ℓ	<0.2
Ag mg/ℓ	<0.002
Al mg/ℓ	200-280
B mg/ℓ	.02-.05
Ba mg/ℓ	.02-.07
Be mg/ℓ	.02-.06
Cd mg/ℓ	.002-.005
Co mg/ℓ	.36-.60
Cr mg/ℓ	.05-.10
Cu mg/ℓ	.14-.22
Fe mg/ℓ	130-180
Mn mg/ℓ	14-24
Mo mg/ℓ	.06-.16
Ni mg/ℓ	1.4-1.9
P mg/ℓ	1.4-2.4
Pb mg/ℓ	<0.02
Ti mg/ℓ	<0.001
V mg/ℓ	.06-.11
W mg/ℓ	<0.01-.03
Zn mg/ℓ	1.1-1.5

FIGURE 7.6.2: TEXTURE OF TAILINGS ON GUNNAR MAIN TAILINGS

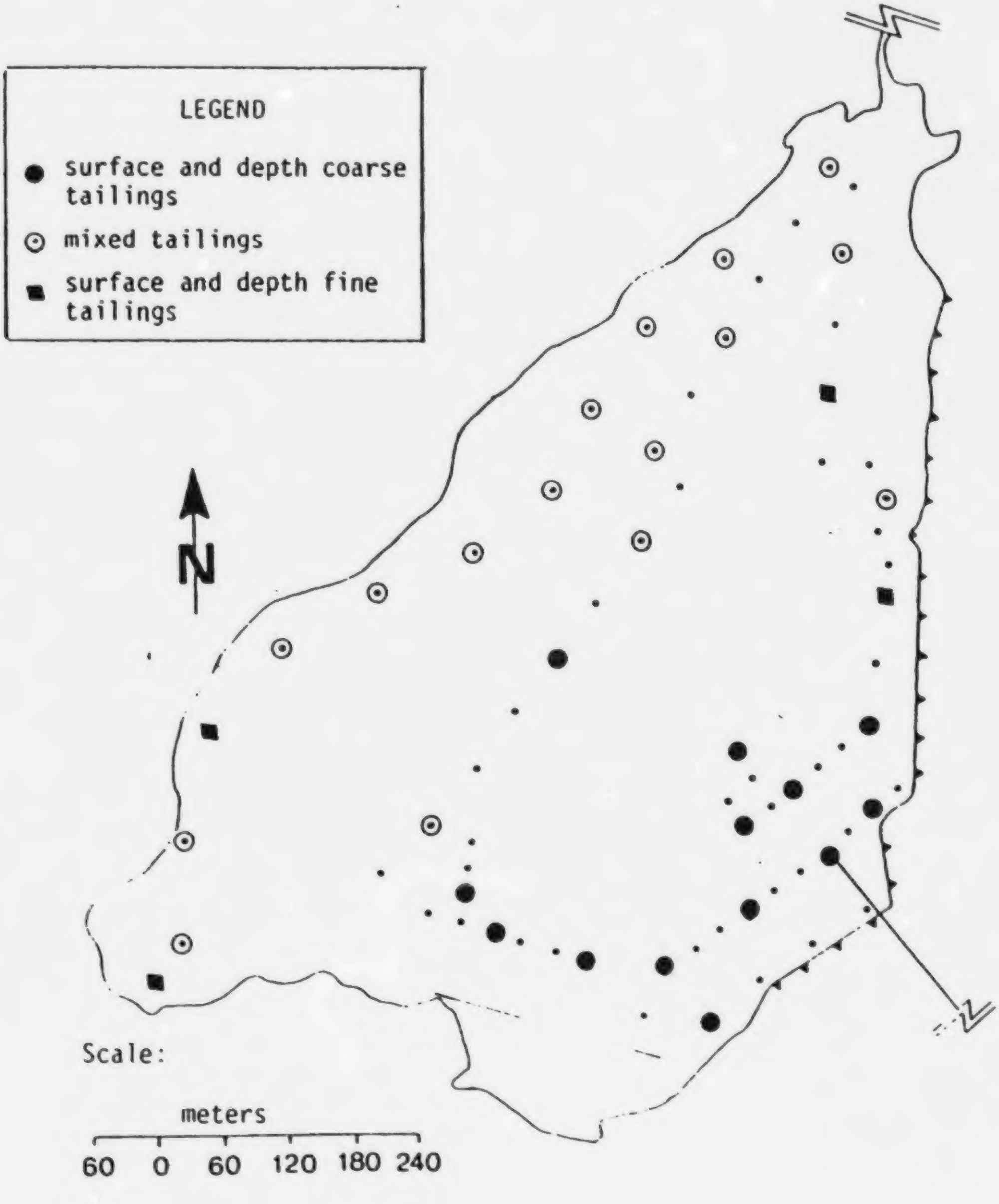
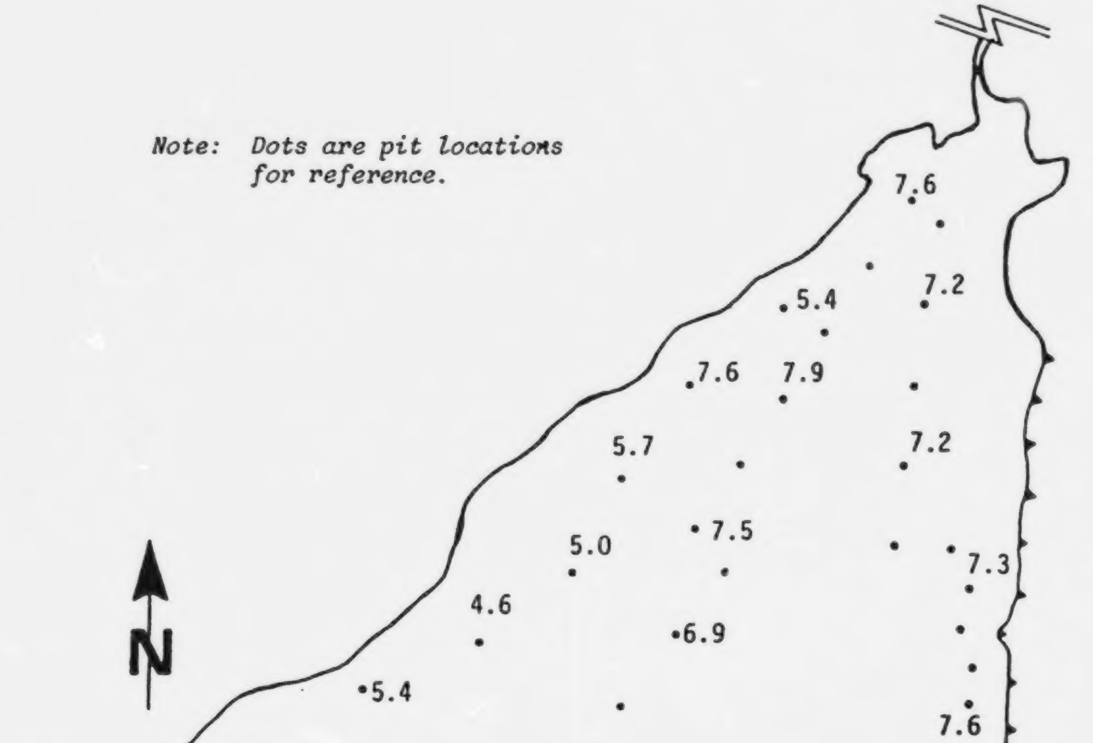

LEGEND
● surface and depth coarse tailings
⊙ mixed tailings
■ surface and depth fine tailings
N
Scale:
meters
60
0
60
120
180
240

FIGURE 7.6.3: DISTRIBUTION OF pH VALUES OF SURFACE TAILINGS ON GUNNAR MAIN


Note: Dots are pit locations for reference.

7.6
7.2
5.4
7.6
7.9
7.2
5.7
7.5
7.3
5.0
4.6
6.9
5.4
7.6
5.7
7.4
7.2
4.0
7.6
7.3
7.7
7.4
7.5
7.4
7.4
7.4
7.5
7.3
4.3
7.5
7.6
7.8
7.5
7.9
N
slurry pipe
pipe
Scale:
meters
60
0
60
120
180
240

FIGURE 7.6.4: DISTRIBUTION OF MOISTURE CONTENT ON GUNNAR MAIN (percent of dry weight)

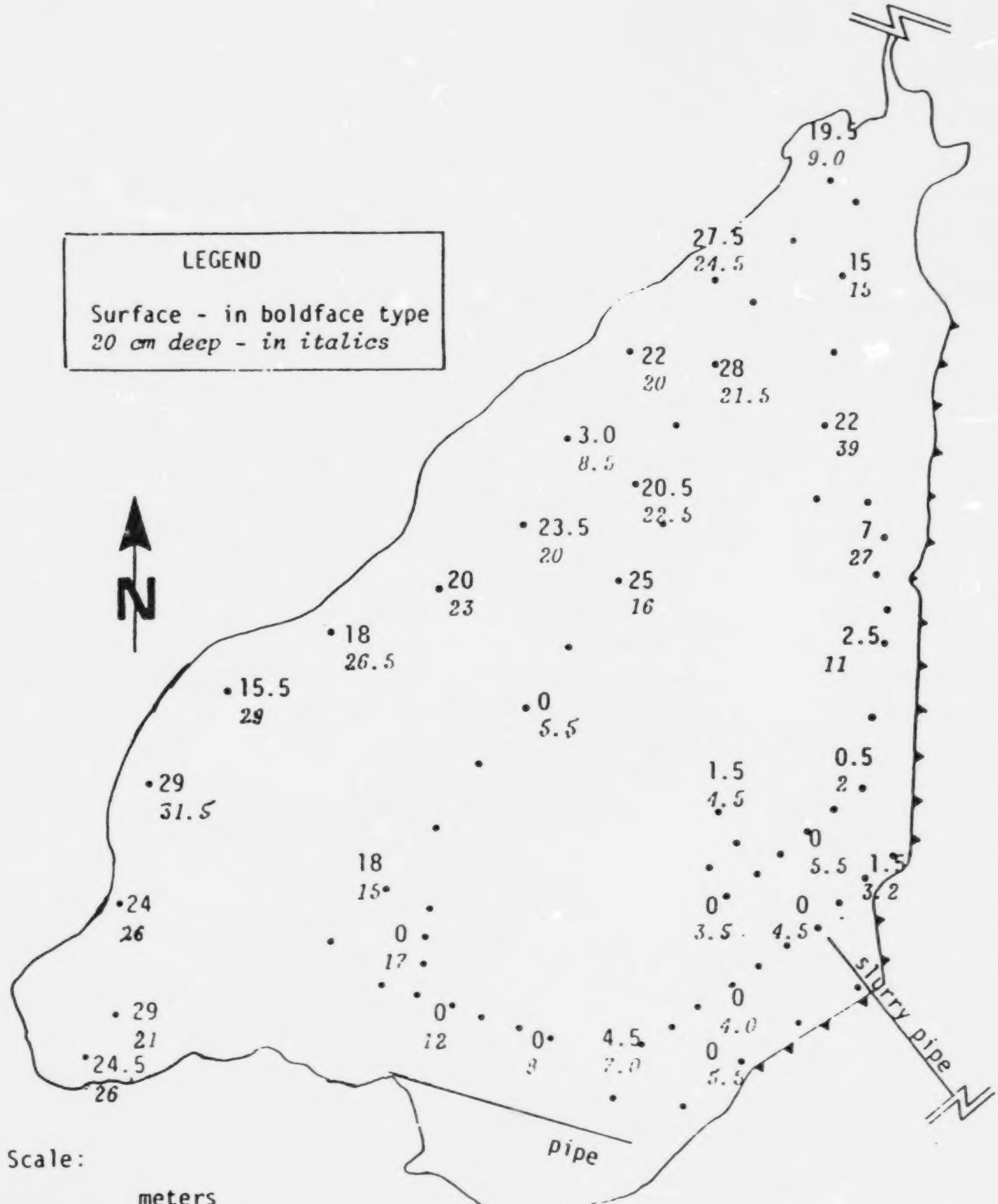

LEGEND
Surface - in boldface type
20 cm deep - in italics
N
19.5
9.0
27.5
24.5
15
15
22
20
28
21.5
3.0
8.5
22
39
20.5
22.5
23.5
20
7
27
20
23
25
16
18
26.5
2.5
11
15.5
29
0
5.5
29
31.5
1.5
4.5
0.5
2
0
5.5
1.5
3.2
18
15
24
26
0
3.5
0
4.5
0
17
29
21
0
12
0
8
4.5
7.0
0
4.0
0
5.5
24.5
26
slurry pipe
pipe
Scale:
meters
60
0
60
120
180
240

TABLE 7.6.43: DISTRIBUTION OF SOME ELEMENTS AND CONCENTRATION FACTORS IN VEGETATION GROWING ON GUNNAR TAILINGS (ug/g dry weight)

		Copper		Nickel		Lead		Uranium		Vanadium		% Calcium	
	Foxtails:												
	GUNNAR NORTH												
	Substrate (pH 6.9)	35.2		7.0		148		113		69		2.89	
	Fruit	5.7	*0.16*	3.4	*0.49*	3.5	*0.02*	2.7	*0.02*	<0.2	*<0.003*	0.070	*0.02*
S3	Leaves and stems	7.6	*0.22*	5.9	*0.84*	10.1	*0.07*	195	*1.73*	3.4	*0.05*	0.81	*0.28*
	Roots	112	*3.2*	20.1	*2.87*	93.4	*0.63*	700	*6.19*	7.4	*0.11*	0.39	*0.13*
	GUNNAR CENTRE												
	Substrate (pH 6.2)	20.6		7.0		121		150		27.6		3.62	
	Fruit	11.0	*0.53*	2.6	*0.37*	3.4	*0.03*	0.71	*0.005*	0.5	*<0.02*	0.10	*0.03*
S2	Leaves and stems	70	*3.40*	30.7	*4.4*	20.1	*0.17*	9.1	*0.06*	0.9	*0.03*	0.20	*0.06*
	Roots	65	*3.2*	11.3	*1.6*	70.3	*0.58*	-	-	-	-	-	-
	GUNNAR SOUTH												
	Substrate (pH 7.1)	23.7		7.5		200		85		21		0.60	
	Fruit	5.6	*0.24*	1.9	*0.25*	9.6	*0.05*	3.2	*0.04*	0.73	*0.03*	0.11	*0.18*
S1	Leaves and stems	17	*0.72*	10.9	*1.5*	21.9	*0.11*	89	*1.0*	1.4	*0.07*	0.19	*0.32*
	Roots	40	*1.7*	8.3	*1.1*	104	*0.52*	350	*4.1*	3.4	*0.16*	0.21	*0.35*
	Calamagrostis sp.												
	GUNNAR CENTRAL												
	Substrate (pH 5.2)	32.9		8.6		124		49		25		0.62	
	Fruit	14.9	*0.45*	8.1	*0.94*	7.0	*0.06*	-	-	-	-	-	-
	Leaves and stems	6.3	*0.19*	7.3	*0.85*	7.0	*0.06*	8.0	*0.16*	<1.9	*<0.08*	0.49	*0.79*
	Roots	37	*1.1*	10.0	*1.2*	33.4	*0.27*	-	-	-	-	-	-
	GUNNAR MAIN												
	Festuca rubra												
	Substrate (pH 7.8)	26.1		5.5		103		111		21		0.88	
	Fruit	15.0	*0.57*	3.2	*0.58*	19	*0.18*	-	-	-	-	-	-
	Leaves and stems	11.4	*0.44*	23.9	*4.3*	10.8	*0.10*	44.6	*0.40*	<0.6	*<0.03*	0.13	*0.15*
	Roots	40	*1.5*	16.8	*3.1*	94.6	*0.92*	-	-	-	-	-	-

Italic numbers are cf's based on the substrate concentrations.

GUNNAR MAIN

Typha latifolia	Seeds	Stems	Leaves	Roots	Rhizomes
COPPER n=2	11.4 ±3.0	5.2 ±0.4	4.2 ±0.6	36.1 ±22.9	7.6 ±3.1
NICKEL n=2	2.7 ±1.0	0.75 ±0.1	1.1 ±0.5	3.6 ±1.2	0.9 ±0.4
LEAD n=2	1.7 ±0.3	1.8 n=1	1.9 ±0.7	740.0 ±141.0	28.0 ±18.0
COBALT n=2	<1.0	<0.2	<0.2	6.2 ±3.2	<0.6

TABLE 7.6.44: WATER CHARACTERISTICS ASSOCIATED WITH AQUATIC VEGETATION ON GUNNAR TAILINGS (mg/L)

	pH	Map Code	U	Mg	V	Al	Mn	Ca	Cond. µ mhos/ cm
Typha pond Central	8.4	T2	3.2	1260	≤0.014	≤0.4	≤0.4	412	7200
Typha pond south	7.7	T1	2.7	153	<0.005	<0.13	<0.13	318	2400
Langley Bay Creek	6.5	7	0.006	<4	<0.002	0.12	<0.06	12.6	120
Lake Athabasca St. Marys Channel	7.6	none	≤0.002	2.5	<0.001	0.11	<0.03	5.5	70

TABLE 7.6.45: TAILINGS AND SOILS CHARACTERISTICS ASSOCIATED WITH GUNNAR VEGETATION

Site description	Map code	Analysis code	pH		Conductivity µ mhos/cm		Moisture loss (%)		L.O.I. (%)	
			1	2	1	2	1	2	1	2
Gunnar dry tailings	1	GW-1,2	7.2	7.02	600	520	0.12	0.33	0.63	0.61
	2	GE-1,2	6.5	6.65	1,500	1,800	3.91	4.42	2.37	2.24
	3	GB-1,2	4.3	4.61	2,800	3,000	29.89	25.06	3.45	2.94
	5	GGP-1,2	7.1	7.01	2,800	2,700	14.87	18.23	0.89	0.84
	4	GSP-1,2	6.4	7.01	9,200	10,000	21.32	22.79	3.93	3.70
	6	GCB-1,2	3.95	4.11	10,000	10,000	5.91	17.54	1.98	1.39
	7	GLB-1,2	6.0	5.79	2,200	2,400	20.80	22.07	1.23	1.29
	T1	TS-3	7.2	7.00	1,100	940	13.41	22.43	0.80	0.58
	T2	TG-3 dry	7.0	6.80	1,500	1,000	18.08	17.56	0.74	0.42
Gunnar waterlogged	T2	TG-3 wet	6.6	6.54	-	2,400	-	24.66	1.46	1.32
Gunnar control soil	8	CH-1	5.8	5.9	105	86	3.41	4.02	8.94	16.20
	9	CL-1	6.0	6.4	85	91	6.38	5.06	10.58	7.62
	-	CW-1	5.55	6.0	72	30	2.17	1.35	2.57	2.61
Grasses/ foxtails	C	GC-3	4.9	6.20	4,800	2,800	3.96	4.89	0.97	0.96
	F	GG-3	7.7	7.8	10,000	10,000	15.35	12.72	1.87	1.61
	S1	FS-3	7.1	6.81	2,800	2,300	3.98	7.57	1.33	1.15
	S2	FC-3	6.2	6.52	4,200	3,400	29.07	25.22	2.76	1.91
	S3	FN-3	6.9	7.01	5,300	4,200	28.04	23.15	2.72	2.57

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7.8 PHOTOGRAPHS

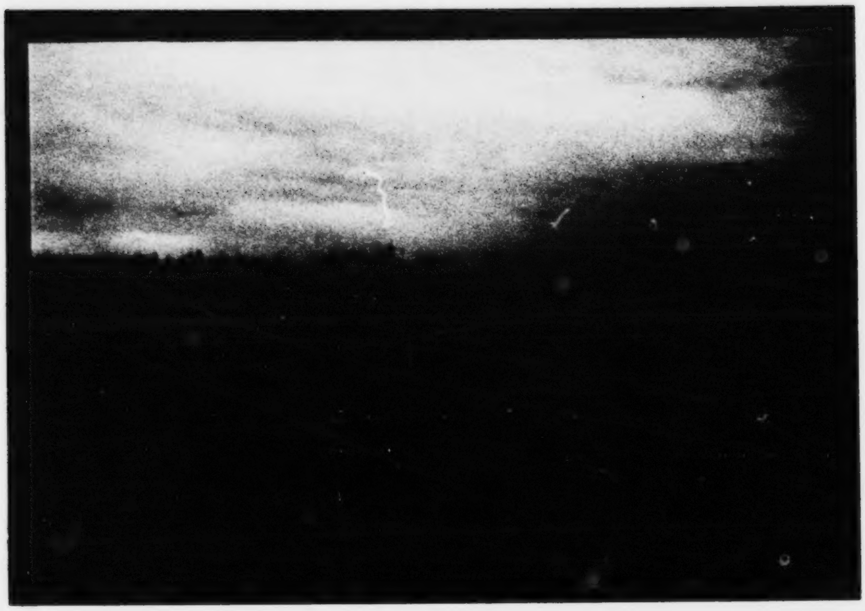

FIGURE 7.8.1: North side of Gunnar Main showing Typha (far left), Grass (foreground and centre) and Shrub (far right) communities.

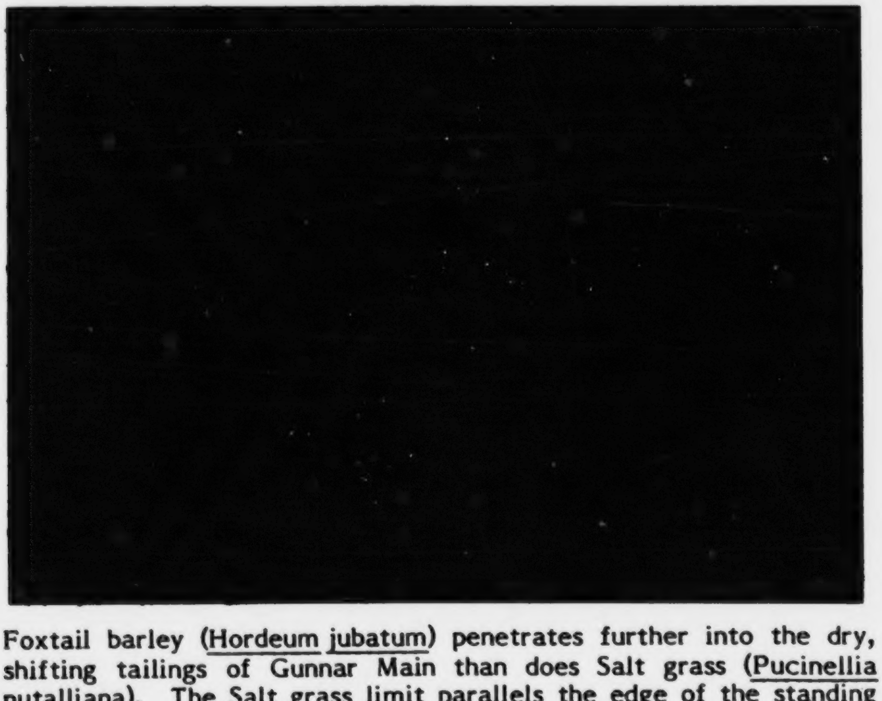

FIGURE 7.8.2: Foxtail barley (Hordeum jubatum) penetrates further into the dry, shifting tailings of Gunnar Main than does Salt grass (Pucinellia nutalliana). The Salt grass limit parallels the edge of the standing water on Gunnar Main.

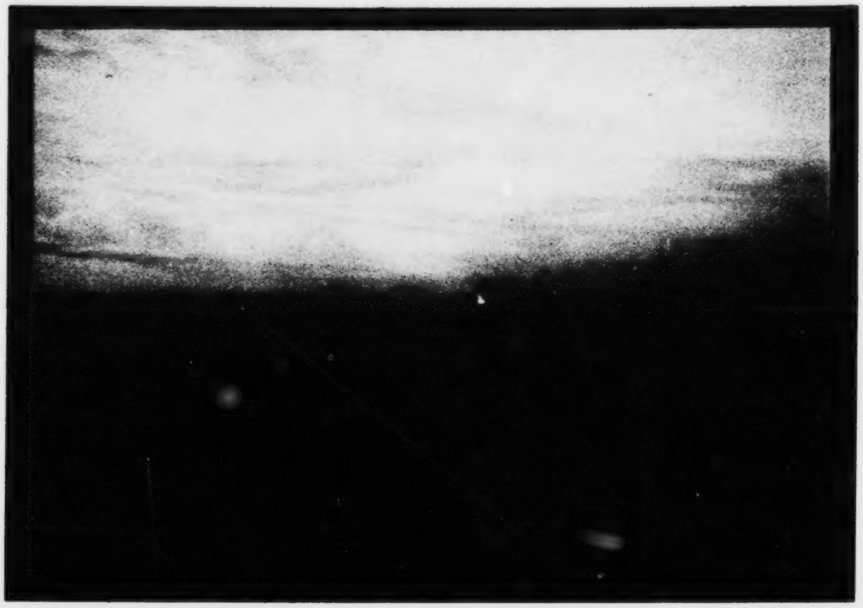

FIGURE 7.8.3: Mud Flat (Juncus) community on Gunnar Main near discharge to Frog Pond.

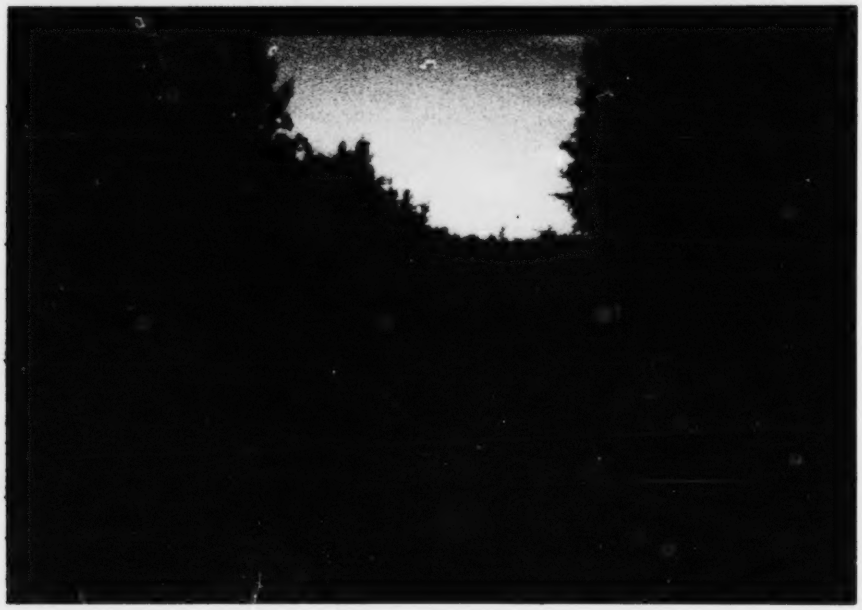

FIGURE 7.8.4: Sedge (Carex) community of Frog Pond near Gunnar Main, with dense Shrub community (Aluns, Salix, Betula) on either side.

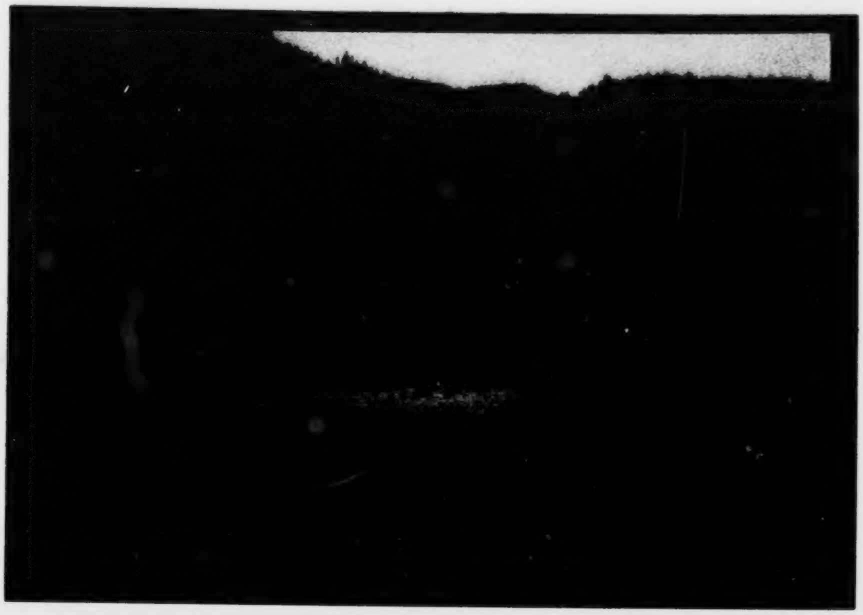

FIGURE 7.8.5: Grass/Sedge (Calamagrostis, Carex) community of Gunnar Central. Note salt encrustation in foreground, standing water in background.

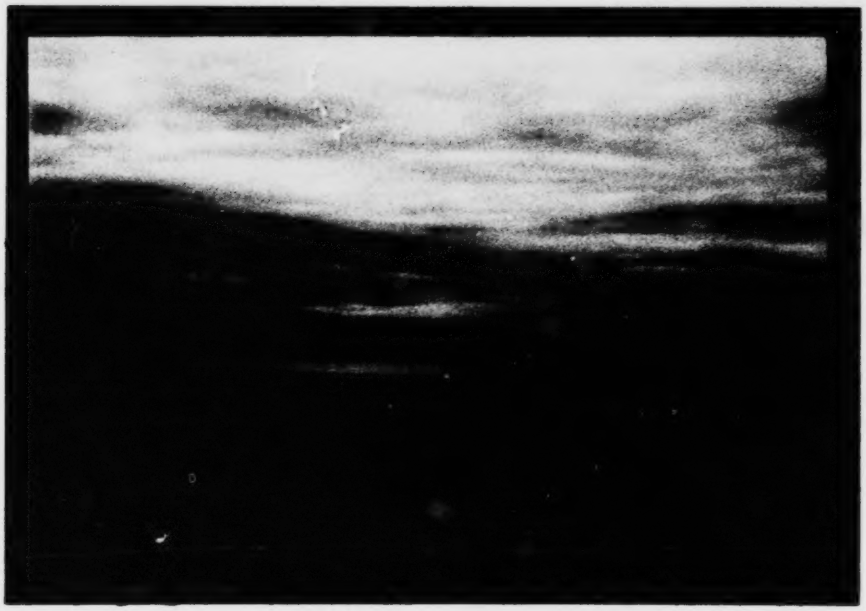

FIGURE 7.8.6: Grass community of Langley Bay Tailings (foreground) gives way to a Sedge/Typha community around the channel connecting Langley Bay and Cut-off Langley (background).

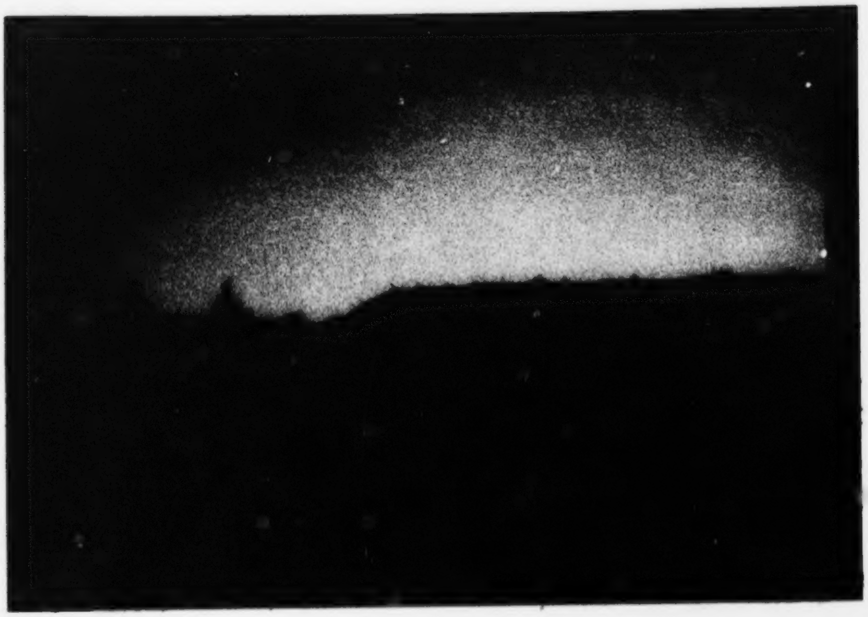

FIGURE 7.8.7: Xeric shrub community of the Waste Rock Pile dominated by weeds and woody shrubs such as Populus and Rubus. Fireweed (Epilobium) gives the pink colour by the roadside.

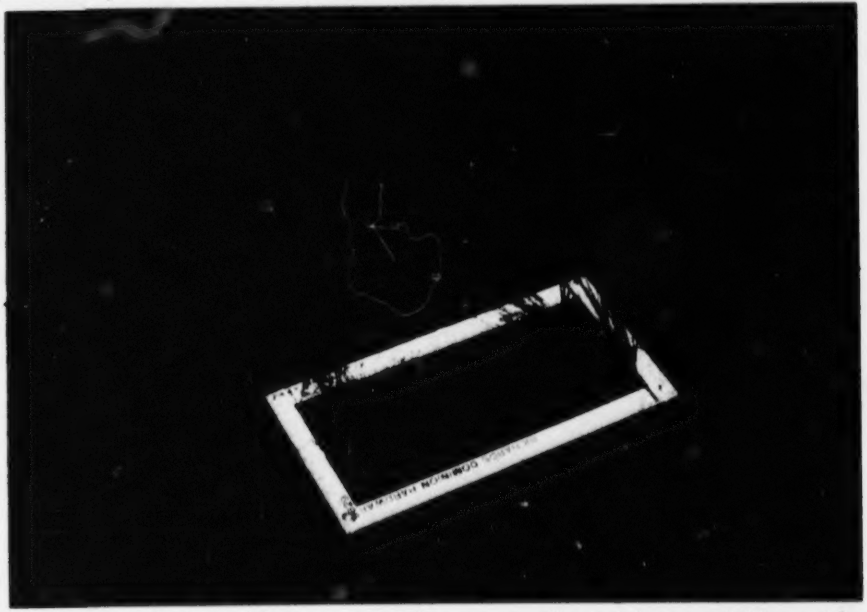

FIGURE 7.8.8: Above-ground plant biomass samples were clipped from within a 1/4 m^2 quadrat, shown here at a sampling point in the mud flat community (Juncus) on Gunnar Main. Ten quadrats were randomly placed in each community.

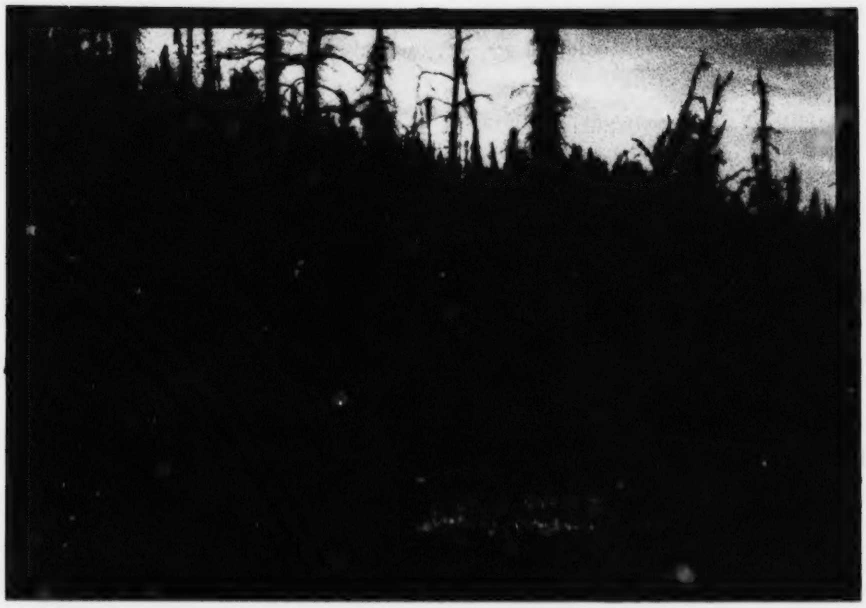

FIGURE 7.8.9: Horsetail (Equisetum) on Gunnar Main is choice summer forage for moose.

FIGURE 7.8.10: Beaver dam maintains water level in the Frog Pond.

Volume

8

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CONTRACT REPORT NUMBER: OSQ 84-00195
VOLUME 8
APPENDIX 7
WASTE ROCK

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
CONTRACT NO. 15SQ.2341-4-1674X
VOLUME 8 - APPENDIX 7
WASTE ROCK

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THE GUNNAR FIELD STUDY

The Gunnar Field Study consists of 10 volumes, each published separately. Volumes 2 to 10 are supplements to Volume 1, written as Appendices 1 to 9.

The 10 volumes are:

- Volume 1 - Summary Report
- Volume 2 - Test Procedures and QA/QC Program (Appendix 1)
- Volume 3 - Atmospheric Studies (Appendix 2)
- Volume 4 - Tailings Solids and Surrounding Soils (Appendix 3)
- Volume 5 - Groundwater (Appendix 4)
- Volume 6 - Surface Water (Appendix 5)
- Volume 7 - Biology (Appendix 6)
- Volume 8 - Waste Rock (Appendix 7)
- Volume 9 - Eating Habits of Local Population (Appendix 8)
- Volume 10 - Permafrost (Appendix 9)

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8.0 INTRODUCTION

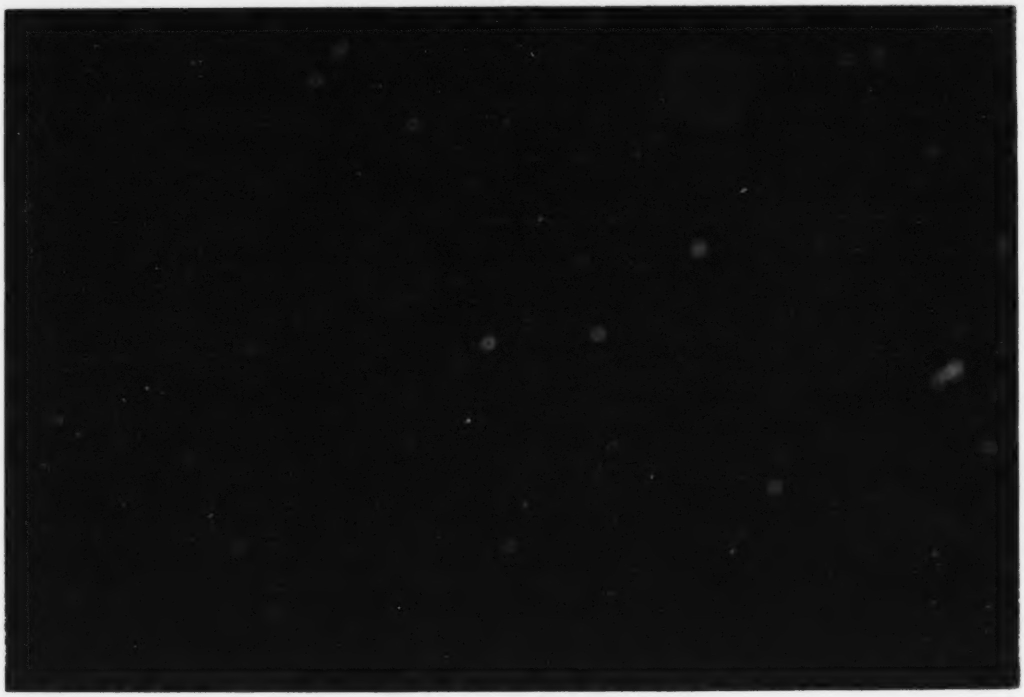
The majority of the waste rock produced during the operation of the Gunnar Mine was stored in 2 interconnecting piles east of the open pit covering an area of approximately 10 ha. These piles form one of the dominant features of the landscape at the site. It is also reported that additional waste rock was used for general site grading and roadway construction. Figure No. 8.1 shows the location of the waste rock piles in relation to the other key elements of the mine/mill complex. Photograph Nos. 8.1 and 8.2 show the waste rock pile from the air as it appeared in November 1984 and August 1985.

The waste rock piles are relatively barren areas with very little vegetation cover. It is reported that the piles are composed primarily of the stripping from the open pit and the waste from the open pit operation. The volume of stripping was estimated at 270,000 m^3 and was thought to have been spread underneath the present waste rock piles. The majority of the waste rock placed in the piles was from the open pit operation and is therefore expected to be relatively coarse in relation to the waste from the underground operations, which was primarily stored underground.

Because the waste rock piles constitute a very significant component of the abandoned Gunnar Mine, it was desired to determine the impact of the rock on the local environment. The characteristics of the waste rock pile which were to be determined as part of the Gunnar Field Study, were set out in the request for proposal and are presented in detail in Section 8.1 - Detailed Requirements. Generally, however, the characterization consists of a number of diverse measurements involving all of the technical disciplines utilized on the project. The approach taken in this report will therefore be to present all information on one characteristic in one section, i.e. design of sampling program, methods used, QA/QC where applicable, and results achieved. To use a more conventional approach in which the report presents the overall sampling plan, all methods and procedures, QA/QC, and results obtained in sequence would be confusing.

PHOTOGRAPH NO. 8.1

Waste rock pile from the air.
August 1984



PHOTOGRAPH NO. 8.2

Waste rock pile from the air.
November 1984

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SITE PLAN

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1:20 000
DATE DEC. '85
DRAWN BY W. T.
APPROVED BY

FIGURE 8.1

Some previous work or studies have been conducted in relation to the Gunnar Waste Rock piles. These studies will be discussed in their appropriate section and are listed in the references in Section 8.9.

An interesting phenomenon which was observed in the winter was what appeared to be streams of water vapour rising from within the rock pile.

8.1 DETAILED REQUIREMENTS

The detailed requirements for the waste rock component of the Gunnar Field Study were set out in the request for proposal and have been included in their entirety as follows:

a) Conduct a volumetric survey at the minesite, estimating as closely as possible without excavation. The survey should include the main piles, mine, townsite and the road to the airport.

b) Conduct a direct radiation survey (gamma) of the waste rock at appropriate intervals. Calibrated readings at 1 m above surface are required; measurements on dangerously sloping surfaces are not required. The area may have been contaminated with windblown tailings or gamma-active industrial refuse; notation of anomalous radiation resulting from these sources should be taken.

c) From the results of the gamma survey, designate 3 refuse-free areas as the following for rock sample collection:

    i) low, less than 10 nC/kg
    ii) medium, 10 to 25 nC/kg
    iii) high, greater than 50 nC/kg

    (These values may need to be adjusted depending on field results.)

d) Collect adequate samples from the 3 locations for determination of the following characteristics:

1) Physical Characteristics

i) Approximate size analysis. Sizes greater than 20 cm should only be estimated.

ii) Bulk density. Simple field measurements only are recommended.

iii) Mineralogical composition. Representative samples should be collected for determination of main mineral composition (greater than 1 percent) and rock type. Petrographic examination is to be undertaken to determine the extent of weathering or alteration that has resulted from surface exposure.

2) Chemical Characteristics

i) Chemical analyses of metals (20) by plasma emission scan. Care should be taken to minimize sample contamination during size reduction for chemical analyses.

ii) Semi quantitative analyses of the following:
$S^=$, CO_2, SiO_4, Al_2O_3, TiO_2, $SO_4^=$.

iii) Radiochemical analyses: U total, Th^{230}, Ra^{226}, Pb^{210}.

e) Determine the radon exhalation rate at the 3 chosen sample locations by track-etch detector methods. A minimum of 3 detectors are to be used at each location, and sampling shall be done in 2 periods, summer and winter.

f) Determine water-leachable constituents from the representative waste rock samples. Constituents of concern are U total, Th^{230}, Ra^{226}. Substantial size reduction for these tests is recommended. Water size reduction for these tests is recommended. Water should be simulated rainwater.

g) Determine the general flow of water of the main waste rock piles. It should be noted that the hydrology of the piles may be complicated by the presence of permafrost. The extent of permafrost in the waste rock pile is to be determined by methods other than excavation.

h) Measure the rate of seepage, where observed, of water from the waste pile. Note that two locations were observed by Tones 1981, (SP-1, SP-3, Figure 2). Determine water quality of seepage and perform radiochemical analyses (U, Th^{230}, Ra^{226}).

i) Conduct a soil sampling program around the periphery of the main waste rock piles. Sampling to a maximum depth of 3 m is recommended, or to bedrock. Soil cover is minimal on the west side. The north and east sides of the pile are boggy and wet and will not support tracked vehicles, except during the winter. Permafrost can be expected in the swampy area on the north side of the waste rock pile.

For each test hole produce a test hole log, with description of materials encountered. Collect samples of distinct soil type sections for analyses. Analyses requirements are U total, Th^{230}, Ra^{226}. Where distinct non-peat soil sections are encountered, produce grain size curves.

j) Survey volunteer vegetation on the waste rock. No chemical analyses of plants are required.

Following the award of the contract, the terms of reference were adjusted in some cases to reflect on site conditions and logistical limitations. These adjustments to the detailed scope of work were as follows:

a) No Change

b) No Change

c) Delete

d) Item 1(ii) Bulk density to be determined from laboratory simulation of field density.
Item 2(ii) Add arsenic and selenium to the analysis.

e) No Change

f) Delete

g) Delete Measurements for Permafrost.

h) Delete Th^{230} From the Analysis and Add Pb^{210}.

i) Delete Th^{230} From the Analysis and Add Pb^{210}.

j) No Change

8.2 VOLUMETRIC SURVEY

8.2.1 Procedures

Topographic mapping of the site was prepared by Prairie Surveys Limited. The late contract award did not permit placing control targets and running up-to-date photo coverage due to the presence of snow cover. The mapping was therefore produced by applying current ground survey control to 1:25,000 air photo coverage from 1976. Topographic maps were produced at a scale of 1:5,000 and enlarged to 1:2,000. Figure Nos. 4.6 and 4.7 in Volume 4, Appendix 3 show the mine/mill complex topography at the 1:2,000 scale with a contour interval of 1 or 2 m. The 1 m interval was used for the flatter terrain and the 2.0 m interval for steeper slopes.

The elevations were determined from on-site benchmarks which were established as follows:

TBM 0 - Top of turnbuckle on a large steel roller drum by the airstrip, assumed elevation 100 m.

TBM 14 - Northeast corner of main shaft building top of steel rail on top of concrete foundation, elevation 75.641 m.

The volume of the waste rock pile was calculated from the contour plans by Prairie Surveys Limited. The calculations assumed that the underside of the pile was a planar surface which coincided with the point where the edge of the pile intersected with ground surface.

No attempt was made to calculate the volume of waste rock used for site grading, roadways, wharfs and the air strip. The projection of these features above the surrounding topography was not sufficient to define the areas accurately and excavations to define the depth were beyond the terms of reference. Any attempt to quantify the volume of waste rock used for these purposes is therefore an estimation.

8.2.2 Volume

The volume of the waste rock piles was calculated to be 2,710,000 m^3. This figure would include the estimated 270,000 m^3 of stripping believed to be at the base of the pile. Although no attempt was made to quantify the volume of waste rock used for other purposes, a visual assessment would suggest a figure of less than 100,000 m^3 or 3.7 percent of the waste pile volume. Certainly it would seem reasonable to assume that a volume equivalent to less than 5 percent of that in the waste piles was used for other purposes.

8.2.3 Potential Errors

The most significant factors affecting the volume estimates in terms of their relative importance would be:

1) The assumption regarding the original topography of ground surface under the pile.

2) The estimates of waste rock not placed in the pile.

3) The accuracy of the volume calculations themselves.

An exercise to quantify these potential sources of error was not considered justified.

8.3 GAMMA SURVEY

8.3.1 Procedures

The gamma emission survey was conducted using the hand-held, multiple range, Berthold "Ratio/F" gamma dose-rate meter. The survey was originally planned for the November 1984 campaign, but due to harsh winter conditions was postponed to the June 1985 campaign.

The survey consisted of split gamma readings taken at the 1 m and 0.2 m levels above the surface at 73 locations on the top of the Waste Rock Pile. Locations were determined using stadia measurements made with a transit set up on top of the Waste Rock Pile at 2 grid locations, 1000 North, 5000 East (horizontal survey control Point No. 25) and 528.847 North, 4744.752 East (a temporary control point on the south end of the Waste Rock Pile). The horizontal measurements were made using the smoke stack at grid location 717.015 North and 4180.631 East (survey control Point No. 26) as the reference. All horizontal angular measurements were made from these control points. Communication was maintained using hand held radios and the notes were kept by the transit operator.

8.3.2 Results of the Survey

The hand-held gamma survey results are presented in Table 8.1 which also shows the information required to locate the readings. In order to determine the location of any point, the following procedure should be used:

1. Identify the setup location on Figure No. 8.1.
2. Turn the appropriate horizontal angle left or right from the zero azimuth line to the smokestack.
3. Calculate the horizontal distance using the vertical angle and the static road readings. Charts are also available for this purpose.
4. Plot the point on Figure No. 8.1.

The material composing the waste rock pile was of too heterogenous a nature for consistent spot gamma readings. Thus a range of readings is shown for each location in Table 8.1. In at least one instance where the 0.2 m reading was considerably higher than the 1 m reading, the cause was found to be the close proximity of a 2.0+ mR/h source. The readings on the waste rock pile were approximately 150 u R/h, regardless of height.

8.4 PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE ROCK

8.4.1 Sampling and Testing Program

A total of 11 surface samples of the waste rock were recovered at locations as shown on Figure No. 8.2. (RP1 to RP11). The samples were recovered by hand excavation and placed in sample bags for shipment. The average size of samples was approximately 20 kg.

Dry sieve analysis tests were performed in the laboratory on Sample Nos. RP2, RP3, RP4, RP5, RP7, RP8, RP9, RP10 and RP11 in accordance with ASTM Standard C136-84 "Sieve Analysis of Fine and Coarse Aggregate".

TABLE 8.1

RESULTS OF GAMMA SURVEY

Setup No. 1: Horizontal Control Point No. 25 (1000 N and 5000 E)
Sighted in on Horizontal Control Point No. 26 - Smoke Stack on West Side of Open Pit by Shop (0° - 00')

Horizontal Angle	Vertical Angle	Rod Reading			1-m Reading (ur/hr)	0.2-m Reading (ur/hr)
		Lower	Middle	Upper		
0°-30' right	0°- 0'	9.52	9.98	10.41	70-110	70-110
15°-20' left	0°- 0'	10.26	10.71	11.16	70- 90	70- 90
15°- 0' left	1°-50' down	8.89	9.70	10.57	120-100	90-100
29°-45' left	1°-50' down	7.85	8.66	9.46	80-100	120-160
29°-45' left	1°-50' down	7.21	7.62	8.03	100-130	100-120
44°- 5' left	1°-50' down	6.82	7.22	7.62	100-140	120-150
44°- 5' left	1°-50' down	6.37	7.18	7.99	100-130	100-120
59°-45' left	1°-50' down	4.58	5.44	6.30	120-140	220-260
59°-45' left	1°-50' down	5.83	6.30	6.76	90-120	70-100
74°-55' left	1°-50' down	4.60	5.07	5.54	200-240	180-210
74°-15' left	1°-50' down	2.50	3.44	4.36	100-140	80-110
74°-40' left	1°-50' down	1.88	3.21	4.59	140-160	160-200
74°-15' left	1°- 0' down	4.73	6.54	8.38	90-110	80-100
74°-20' left	1°- 0' down	2.70	4.89	7.09	30- 50	30- 50
74°-20' left	1°- 0' down	5.59	8.52	11.39	40- 70	40- 60
90°- 0' left	0°-27 1/2' up	6.54	8.80	11.10	120-160	260- 30
90°-25' left	0°-17' up	7.18	9.10	11.02	60-100	70-100
90°-20' left	0°-07' up	7.00	8.50	9.99	370-410	430-470
90°-20' left	0°-08' up	6.59	7.64	8.70	70-100	70-100
92°-30' left	0°-02' up	5.30	5.91	6.51	40- 70	50- 80
104°-55' left	0°-00'	2.91	3.52	4.09	80-110	90-130
105°-15' left	0°-00'	1.42	2.41	3.42	60- 80	50- 60
105°-15' left	1°-16' up	6.78	6.29	9.78	100-130	90-120
105°-20' left	1°- 0' up	7.78	9.62	11.53	140-180	140-180
119°-50' left	1°-28' up	6.05	7.40	8.71	240-280	280-320
					top of pile of smaller debris	
120°-15' left	1°-28' up	2.12	3.06	4.00	330-360	510-560
120°-10' left	1°-28' up	3.07	3.63	4.20	430-470	480-530
134°-50' left	2°-10' up	5.12	5.67	6.23	220-260	260-300

TABLE 8.1 (continued)

Setup No. 2: At Point at Far End of Waste Rock Pile (528.847 N, 4744.752 E) Sighted on Smokestack (0° - 00')

Horizontal Angle	Vertical Angle	Rod Reading			1-m Reading (uR/hr)	2-m Reading (uR/hr)
		Lower	Middle	Upper		
75°-00' left	2°-08'down	2.26	3.10	3.95	60- 80	70- 90
60°-00' left	2°-08'down	3.82	4.35	4.83	50- 70	30- 50
60°-00' left	2°-08'down	3.30	4.21	5.10	90-120	80-100
59°-45' left	2°-08'down	2.95	4.28	5.59	130-160	120-150
45°-00' left	1°-26'down	3.80	5.59	7.38	150-180	170-210
45°-00' left	1°-26'down	1.98	3.40	4.78	120-150	160-190
44°-45' left	1°-26'down	4.69	5.66	6.63	90-120	90-120
45°-00' left	1°-26'down	4.08	4.62	5.17	130-160	120-160
30°-00' left	1°-26'down	3.19	3.73	4.27	110-140	90-110
30°-00' left	1°-08'down	3.02	4.05	5.07	120-160	150-180
29°-45' left	0°-36'up	9.13	10.62	12.12	220-260	440-500
29°-45' left	0°-36'up	8.40	10.34	12.28	140-180	210-250
30°-00' left	0°-38'up	5.50	7.90	10.29	60- 80	70- 90
15°-00' left	0°-20'down	0.77	3.00	5.28	120-150	110-140
15°-00' left	0°-20'down	5.29	8.03	9.76	120-160	120-140
15°-00' left	0°-20'down	6.65	7.94	9.21	70-100	50- 80
15°-00' left	0°-20'down	6.74	7.55	8.36	50- 80	50- 60
14°-45' left	0°-20'down	6.02	6.50	6.98	100-140	120-160
0°-20' left	0°-00'	7.66	8.14	8.60	60- 80	60- 80
0°-20' left	0°-00'	8.45	9.36	10.30	40- 60	40- 60
0°-15' right	0°-00'	8.44	9.80	11.16	60- 80	70- 90
0°-15' right	0°-00'	6.92	8.73	10.54	140-290	200-240
0°-00'	0°-00'	7.05	9.28	11.50	110-140	80-110
14°-20' right	1°-30'down	2.18	4.06	5.98	70- 90	70- 90
14°-20' right	1°-30'down	1.60	3.05	4.51	40- 60	60- 70
14°-15' right	1°-30'down	2.65	3.67	4.71	40- 60	50- 70
14°-20' right	1°-30'down	5.34	5.89	6.45	70- 90	60- 80
30°-15' right	1°-30'down	5.25	5.73	6.22	60- 80	70-100
30°-15' right	1°-30'down	3.93	4.85	5.75	40- 60	30- 50
30°-15' right	1°-30'down	4.70	6.00	7.31	70-100	80- 90
30°-00' right	1°-30'down	6.30	8.02	9.75	50- 70	60- 70
45°-00' right	2°-22'down	5.40	8.07	10.72	60- 80	70- 80
45°-00' right	2°-22'down	5.50	7.78	10.00	60- 90	60- 70
45°-00' right	2°-22'down	4.66	6.42	8.18	50- 80	50- 80
45°-00' right	2°-22'down	3.15	4.48	5.80	70- 90	70- 90
45°-00' right	2°-22'down	3.51	4.39	5.26	140-160	280-320
45°-15' right	2°-22'down	4.05	4.58	5.12	60- 80	80-100
60°-00' right	2°-22'down	3.85	4.35	4.82	60- 80	70- 90
60°-15' right	2°-22'down	4.75	5.70	6.62	90-110	120-140
60°- 0' right	2°-22'down	5.05	6.45	7.86	90-110	100-120
60°- 0' right	2°-22'down	6.38	8.18	10.00	50- 70	60- 90
60°-15' right	2°-53'down	4.38	6.60	8.85	30- 70	60- 70
75°-15' right	2°-53'down	4.49	6.19	7.89	70- 90	80-100
75°-20' right	2°-53'down	2.72	3.98	5.22	40- 60	30- 50
75°-30' right	2°-53'down	1.51	2.28	3.06	160-190	120-160
At transit location					80-110	120-140

Transit 5.3' above ground

Notes: 1) The hand-held gamma survey readings are in milli-Rehms per hour.

2) The angle from the smokestack (Point No. 26) when setup on Point No. 25 turned to the temporary setup at the south end of the Waste Rock Pile was 42° 30'.

3) From the setup at the south end of the Waste Rock Pile the angle from Point No. 25 to the smokestack was 100° 00'.

Field density measurements were not considered to be practical during the field campaigns. Two laboratory unit weight measurements were made, however, using the shovelling procedure in ASTM Standard C29-78 "Unit Weight and Voids in Aggregate". This procedure was thought to slightly underestimate the density in the field. The tests were performed on the minus 200 mm material only and because of limited sample size, the 0.014 m^3 mold was used instead of the required 0.028 m^3 mold.

Sample Nos. RP1 and RP6 were submitted to Saskatchewan Research Council for chemical, mineralogical, petrographic and radionuclide testing. The test procedures used and the QA/QC pertaining to them are presented in Volume 2, Appendix 1, Test Procedures and QA/QC Program.

Because of concern with respect to the migration of windblown dust from Gunnar Main Tailings, the minus 35 um material was removed from all 11 samples, combined and submitted to SRC for sulphate and radionuclide easting.

8.4.2 Results of the Tests

8.4.2.1 Physical Characteristics

Some boulder size material was noted on the surface of the pile, but in accordance with the terms of reference, was not sampled. The maximum size of the particles in the samples recovered was 200 mm. The results of the 9 sieve analyses were combined to give a blended gradation which is shown on Figure No. 8.3. The combined gradation was 8 percent cobbles, 86 percent gravel sizes, and 6 percent sand, silt and clay sizes.

WASTE
ROCK

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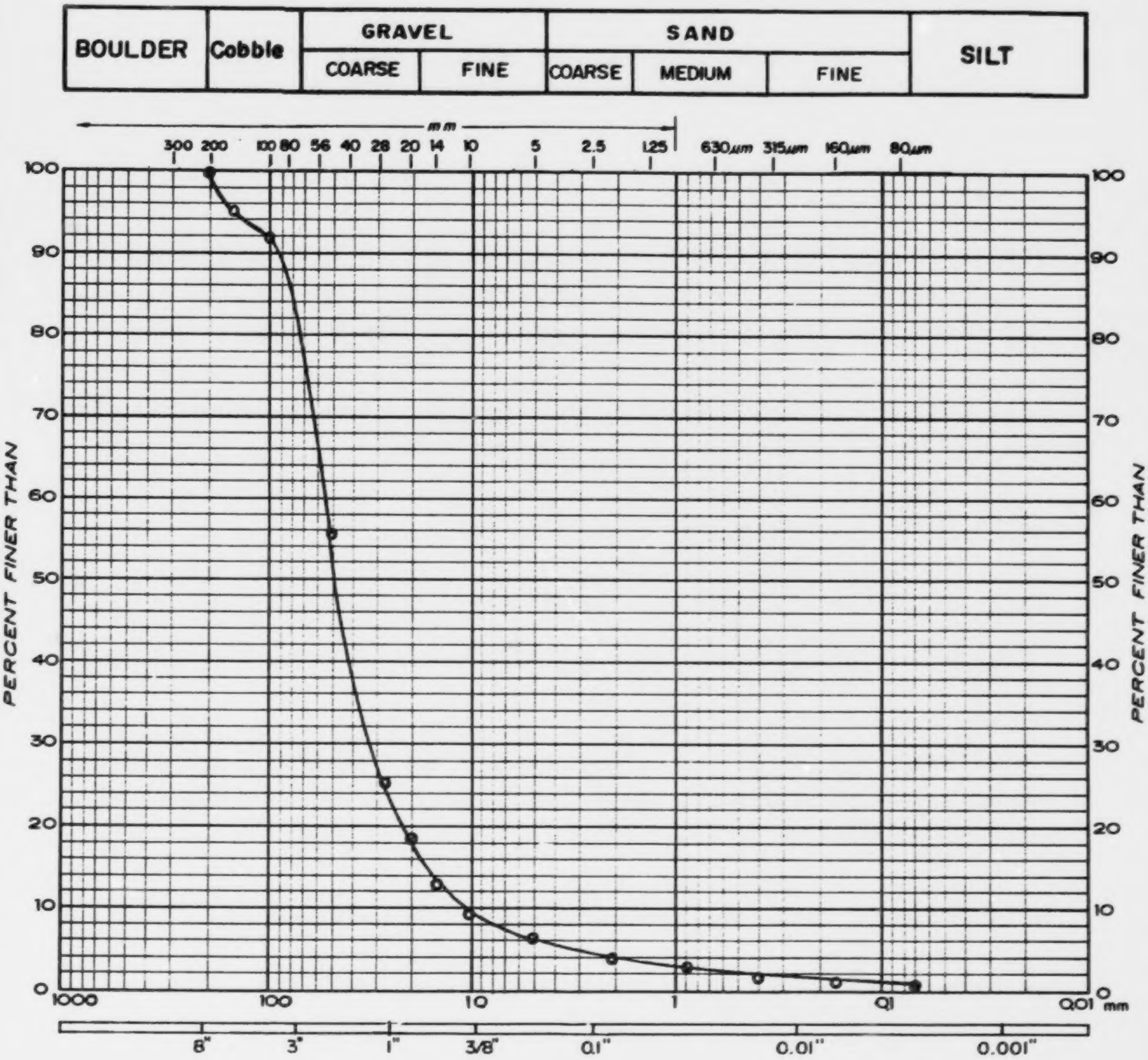
WASTE ROCK SAMPLE LOCATIONS.

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1: 5000	DRAWN BY W.T.	FIGURE 8.2
DATE JAN.86	APPROVED BY	



Dry sieve analysis of waste rock.

REMARKS: *Samples combined RP2, RP3, RP4, RP5, RP7, RP8, RP9, RP10 AND RP11*

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NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No. __________ Depth __________

DRAWING NO:
FIGURE 8.3

The results of the 2 bulk density tests are summarized in Table 8.2.

TABLE 8.2
RESULTS OF LABORATORY BULK DENSITY TESTS

Location No.	Unit Weight (kg/m^3)
RP11	1459
RP10	1584

The use of the smaller than specified mold probably introduced some error into the tests, but this error was not considered significant in view of the fact that the tests were being used to approximate a field condition.

Four petrographic examinations were made on subsamples of the waste rock. The results of these 4 examinations are described as follows:

RP-1A Highly Cataclastic Rock

The rock consists of plagioclase, microcline and quartz accompanied by small amounts of chlorite and hematite. Plagioclase, K feldspar and quartz are present in approximately equal proportions.

Larger grains (up to 1 mm) of these minerals are intensively brecciated and crushed to fine-grained masses which form a matrix to relict fragments of the original rock.

Hematite and chlorite are restricted to fractures and grain boundaries.

RP-1B Severely Altered Rock

The rock consists of pale green chlorite and calcite, accompanied by some albite. Calcite and chlorite are intimately intergrown and form an irregular patchy texture. Fractures are filled with chlorite. A few large calcite crystalloblastic grains (up to 1 cm) are set in a fine-grained patchy matrix. Such grains contain spherulite aggregates of chlorite. Relict plagioclase is subjected to sericitization.

RP-1C Relatively Fresh Rock

The rock has a gneissic texture and consists of plagioclase, K feldspar, quartz and chlorite. Quartz forms large (several mm) lensoid concentrations that are composed of strained metamorphic grains. Intervening areas consist of dense feldspathic masses, which are composed of recrystallized, equigranuloblastic grains of plagioclase and K feldspar. Chlorite is present as thin seams parallel to the gneissosity and is pseudomorphous after biotite. Some of the biotite is intergrown with muscovite. A few of the plagioclase grains are altered to sericite. Accessories include zircon and apatite.

RP-6A Hydrothermally Altered Rock

This rock consists of plagioclase (albite), calcite and chlorite.

Plagioclase is the main mineral (-80 percent) and forms granuloblastic masses of interlocking grains. Individual grains may display chessboard texture. A few grains bear evidence of sericitization.

Plagioclase is corroded and invaded by carbonate (calcite) which forms patches made up of irregular granuloblastic individuals. Calcite is present in approximately 10 percent.

Along fractures and grain boundaries, plagioclase is replaced by pale green chlorite (10 percent) which locally forms dense, fine-grained masses that are associated with accessory rutile, zircon and apatite.

The degree of weathering was minimal and could not be estimated by the thin section examination technique.

8.4.2.2 Chemical Characteristics

The results of the chemical analysis on the combined sample of the waste rock are presented in Table 8.3. Table 8.4 presents the results of sulphate and radionuclide tests on a total sample of the waste rock and also on the minus 35 um dust portion only. The radionuclide concentrations in the dust were approximately 1 order of magnitude higher than in the waste rock itself. Sulphate analyses were carried out as tracers in order to determine how much of the fine material in the waste rock may be of a windblown tailings origin. The fine fraction of the tailings that is likely to be transported as far as the waste rock pile, is high in sulphate, whereas the waste rock itself is relatively low. Thus, the presence of high sulphate the dust would suggest a tailings dust origin. The data show that the dust fraction of the waste rock is, relative to the tailings, low in sulphur with only a slight elevation above that for the waste rock itself. This suggests that most of the radionuclides in the waste rock dust originate from the waste rock itself and not the tailings.

The other line of evidence in this regard is the relative activity level. In both the waste rock and the waste rock dust, the uranium is in approximately secular equilibrium with its decay products. In the tailings, the uranium is less than 10 percent of its equilibrium value, reflecting the better than 90 percent extraction efficiency obtained in the mill. If the waste rock dust was derived from the tailings, the activity level of the uranium would be less than that of its daughters. It is similarly suggesting a waste rock origin. The enhancement of activity levels in the dust relative to the bulk of the waste rock relates to the fact that uranium mineralization in the waste rock is found in fractures. When the waste rock is blasted and broken up, it breaks preferentially along fractures. These fractured surfaces then abrade and produce dust enriched in uranium and its decay products.

TABLE 8.3
RESULTS OF CHEMICAL ANALYSIS
WASTE ROCK PILE
SAMPLE NOS. RP1 AND RP6 COMBINED

Constituent	**Amount (%)**
Al_20_3	16.8
Fe_20_3	4.08
CaO	5.12
MgO	4.12
K_20	0.95
Na_20	7.52
Ni	18 *
Pb	30 *
Mo	5 *
P_20_5	0.11
Zn	36 *
Cd	1 *
Co	5 *
MnO	0.049
Cr	87 *
V	43 *
Be	2 *
Cu	25 *
$Ti0_2$	0.30
Zr	139 *
Y	20 *
La	90 *
Th	35 *
Sr	94 *
Ba	284 *
$Si0_2$	62.1
CO_2	2.3
As	3.0 *
Se	0.2 *
S	0.036

* Concentrations in ug/g.

TABLE 8.4
RADIONUCLIDE AND SULPHATE TEST RESULTS ON WASTE ROCK AND DUST

	Concentration	
	Waste Rock	**Dust (<35 um)**
Total S as SO_4 (%)	0.078	0.12
Pb^{210} Total (Bq/g)	1.9	18
Ra^{226} Total (Bq/g)	2.5	20
Th^{230} Total (Bq/g)	1.3	20
Po^{210} Total (Bq/g)	--	18
U Total (ug/g)	116	1750
U Total (Bg/g)	1.4	21.5

8.5 RADON EXHALATION

8.5.1 Sampling Plan

To quantify the extent of the impact of the Waste Rock Pile, radon flux measurements were to be made at areas of high gamma activity. This strategy required that spot gamma measurements be made with the multiple range Berthold "Ratio/F" gamma dose-rate meter before mat sites could be selected. A survey of the waste rock pile in April 1985 showed no particular anomalies in the spot gamma measurements, and therefore, secondary mat siting criteria were employed.

One of the difficulties of utilizing the mat technique for measuring flux is to ensure that a diffusion barrier of the correct properties is installed. These properties include the ability of the barrier to distort the equal radon concentration lines so that surface measurements approximate values for greater depth. Sealing of the edges of the mat thus becomes important. To achieve the base seal, the mat site chosen was:

- Undisturbed; no drill holes or other activity had been conducted.
- Free of holes or voids which could change the diffusion patterns.
- Of uniform granular surface nature with no visible large rocks.
- Close to the center of the pile to minimize the edge effect of the pile.

8.5.2 Field Procedures

One large mat (approximately 3 m by 3 m) was deployed on the northern waste rock pile in April 1985. Five cups were placed under the mat, one at the center, 2 at a distance of 0.45 m from the center on opposite sides of the center cup, and 2 at a distance of 0.9 m from the center on opposite sides of the center cup and on a line perpendicular to the axis formed by other cups. This pattern of deployment was selected to assess the mat seal at the edges since it was thought that sealing would be more difficult on the waste rock pile due to the greater surface porosity.

Two gamma dosimeters were also installed on a wooden stake beside the mat.

All readings were made in the period April to August 1985. Attempts were made to carry out gamma readings in March, but the severe weather and cold made this impossible.

8.5.3 Data Presentation

The mat data for the 5 samples under the large mat on the waste rock pile are summarized in Table 8.5. No determination of flux rates can be made since cans were not installed on the surface. However, the data illustrate several features of the waste rock.

- The values show good agreement. While standard deviations for the data are in the order of 10 percent (derived from counting statistics), the low range of values illustrates that few problems were experienced with the mat technique providing a representative level.
- Generally, the radon levels are significantly lower than those on the tailings, 200, 400 p Ci/l versus 20,000 to 40,000 p Ci/l on the tailings. This is not unexpected, since the mineralization would be anticipated to be much lower.

The gamma dosimeter levels on the waste rock pile were approximately 150 uR/hr. regardless of height.

TABLE 8.5

WASTE ROCK RADON MAT DATA

Site	Detector No.	Installation Date	Collection Date	April-June p Ci/L	June-August p Ci/L
Center	18283	85/05/01	85/06/24	254	
	18222	85/06/24	85/07/27		222
0.9 m North	18282	85/05/85	85/06/24	199	
	18290	85/06/24	85/07/27		290
0.9 m South	18281	85/05/01	85/06/24	249	
	18224	85/06/24	85/07/27		224
0.45 m East	18284	85/05/01	85/06/24	256	
	18221	85/06/24	85/07/27		221
0.45 m West	18285	85/05/01	85/06/24	361	
	18223	85/06/24	85/07/27		223

8.6 FLOW AND COMPOSITION OF GROUNDWATER IN THE PILE

8.6.1 Field Program

Previous work by Tones' 1981 had identified flows of groundwater out of the waste rock pile at 2 locations. The most significant flow was observed between the 2 main lobes of the pile adjacent to Test Hole No. WR4. The zones of seepage were very difuse, however, and quantitative flow measurements would have been extremely costly and difficult to obtain. It was subsequently decided in consultation with NUTP to not proceed with quantitative flow measurements.

Water samples were recovered from the flow out of the pile adjacent to WR4 in June and August, 1985.

8.6.2 Laboratory Testing Program

A complete suite of chemical and radionuclide tests was performed on the June sample, with a partial chemical analysis on the August sample. Please refer to Volume 2, Appendix 1 for test procedures and the QA/QC.

8.6.3 Results of the Tests

The results of the chemical and radionuclide testing are presented in Table 8.6.

The flow from the waste rock pile at WR4 was estimated to be 1 to 2 litres per second in June 1985. Because of the high porosity of the waste rock, significant mounding of the water table below the pile is not anticipated. The seepage which is originating near Test Hole No. WR4 may in large part be surface runoff from the north of the pile originating along the airport road, which ponds on the north side of the pile and flows through the base of the pile and above the underlying clay, eventually discharing near WR4.

A review of the seepage water quality data indicates that the chemistry is not constant, but rather shows both marked local and seasonal variation. Two sets of samples were collected in June, 2 days apart, from the seepage source directly at the face of the waste rock. This seepage zone extends over a length of about 20 m near WR4. The rock at this point lies on the silty clay, and the seepage discharges at the interface between the clay and the rock. The samples collected in June were collected from 2 seepage areas located about 10 m apart. The data reflect a general similarity in the major water quality parameters, with differences from 2 to 3 times for some of the trace elements and major cations. The higher values shown on Table 8.6 for the June sample are judged to be the correct values because of their agreement with both the electroneutrality balance and the check laboratory.

The samples collected in August, when seepage flows were lower, were collected about 10 m down from the seepage face where the majority of the seepage had merged into a small stream with a flow of about 1 litre per second. The levels of major water quality parameters were lower in August by about a factor of 2. This would appear to be a significant change from the June data and may reflect a higher level of recent rain infiltration and less 'groundwater' input. This is also suggested by the relatively low pH and alkalinity values at the end of August. On August 24 and 25, the site received about 20 mm of rainfall, which was 3 days prior to the samples being collected, suggesting a relatively rapid hydraulic response.

The flows in August 1985 would appear to be lower than in August 1981, when seepage from the Waste Rock Pile was sampled by Tones. The smaller seepage stream noted by Tones on the south side of the Waste Rock Pile in 1981 was not present in 1985 and the more significant seepage stream on the eastern side had a flow of about 30 percent of that noted by Tones in 1981. The general seepage water chemistry as recorded in August 1981 and in June 1985 was similar. The August 1985 samples were lower reflecting differences in summer rainfall between the 2 years. The radium 226 value recorded in June 1985 was about 10 times higher than that recorded in August 1981, but the uranium value was about 10 times lower and the lead 210 value 3 times lower. Even after considering the analytical uncertainty involved, it would appear that this seepage source shows very real and marked seasonal and yearly variations that are dependent upon the particular yearly and seasonal precipitation patterns.

TABLE 8.6

GUNNAR WASTE ROCK SEEPAGE WATER QUALITY DATA

Location	Seepage Creek on East Side of Waste Rock Pile	Seepage Creek on East Side of Waste Rock Pile
Depth from Surface	Surface	Surface
Parent Material	Surface flow in small creek approx.5 L/s	Surface flow in small creek approx. 1 L/s
Field Code	WRS	WRS
Date	85.06.20/24	85.08.28
Parameter		
pH	7.8 (8.3)	6.1
Acidity ($CaCO_3$) (mg/L)	4	-
Alkalinity ($CaCO_3$) (mg/L)	107 (116)	39
Conductivity (umhos/cm^2)	1,380	580
Total Dissolved Solids (105°C) (mg/L)	1,380 (1,580)	-
DOC (mg/L)	14.0 (16)	34
DIC (mg/L)	17.0 (25)	-
Kjeldahl-N (mg/L)	0.35	-
Major Anions (mg/L):		
Bromide	L 0.5 (0.20)	-
Chloride	20 (14)	8.0/7.5
Fluoride	0.5 (0.78)	0.4/0.4
Sulphate	770 (930)	270
O-Phosphate	-	L 0.1
Nitrate	L 0.5	0.5
Nitrite	-	L 0.1
Major Cations (mg/L):		
Magnesium	29//59 (70)	39
Calcium	99//290 (298)	74
Iron	0.27 (0.34)	0.26
Manganese	0.20 (0.25)	0.43
Silica SiO_2	13.7 (7.5)	6.3
Aluminum	0.72//0.96 (0.65)	0.40
Sodium	12.0//25 (43)	14.3
Potassium	1.52//2.4 (2.3)	5.3
Trace Cations (mg/L):		
Strontium	0.25//0.67 (0.47)	0.39
Lead	0.06 (L 0.005)	0.33
Cobalt	0.02 (0.002)	0.22
Nickel	0.01 (0.008)	0.025
Zinc	0.015 (0.049)	0.020
Chromium	L 0.01 (0.002)	0.010
Copper	0.015 (0.031)	0.015
Cadmium	L 0.005 (L 0.001)	0.005
Barium	0.03//0.04 (0.058)	0.040
Vanadium	0.01//0.02 (0.01)	0.015
Titanium	-	0.11
Arsenic (ug/L)	-	-
Selenium (ug/L)	-	-
Molybdenum	0.04//0.08 (0.006)	0.07
Beryllium	L 0.01//L 0.01 (L 0.001)	L 0.005
Sum Anions	18.7 (22.1)	-
Sum Cations	20.5 (22.3)	-
Tritium (T.U.)	-	-
Radionuclides		
Uranium (ug/L)	2,000	-
Thorium-230 (Bq/L)	-	-
Radium-226 (Bq/L)	1.1	-
Lead-210 (Bq/L)	0.05	-
Polonium-210 (Bq/L)	-	-
Radium-228 (Bq/L)	-	-

L = Less than.

* Average value.

Value//Value - Means analyses replicated on 2 separate bottles.

Value (Value) - Means replicated analyses on 2 separate samples by 2 separate laboratories.

8.7 SOIL SURROUNDING THE PILE

8.7.1 Field Program

A total of 5 test holes were drilled in the area surrounding the waste rock pile in June 1985 at locations shown on Figure No. 8.2. The test holes were drilled with a hand auger to a depth of 1.0 m. A soil sample was recovered from each hole at the 1.0 m depth, sealed in a plastic bag and labelled. These samples were then transported to the appropriate laboratories for testing.

After the completion of drilling and sampling, a piezometer was installed in each test hole in accordance with the procedures outlined in Volume 5, Appendix 4 - Groundwater.

8.7.2 Laboratory Testing Program

Physical testing consisted of hydrometer grain size analysis tests on the samples from Test Hole Nos. WR3, WR4 and WR5. The tests were performed in accordance with ASTM D422-63 "Particle Size Analysis of Soils".

Chemical and radionuclide tests were performed on 1 soil sample from each test hole. The chemical testing was performed by IEC BEAK and the radionuclide testing by Saskatchewan Research Council. Please refer to Volume 2, Appendix 1 for test procedures and QA/QC on these tests.

8.7.3 Results of the Testing Programs

The test hole logs for the 5 test holes are presented as Figure Nos. 8.4 to 8.8 and the grain size analyses are presented as Figures Nos. 8.9 to 8.11. Basically, all 5 test holes encountered a thin 0 - 3 cm layer of organic topsoil overlying silty varved clay. The properties of the clay were similar to those recorded for the clays underlying the tailings piles.

The results of the chemical and radionuclide tests are presented in Table 8.7.

The geochemistry results at WR1 show that the general chemistry is similar to that found in the clay under Gunnar Central, with the exception of higher leachable iron but lower total iron. These 2 types of clays are mainly characterized by leachable sulphates over 1000 ug/g. The other 4 silty clay samples showed lower soluble sulphate values and generally lower values of other major cations such as calcium. The silty clay at WR4 is different from all of the other silty clay samples around the waste rock pile, in that it contains a high level of soluble chloride at least 10 times that of the silty clay underlying the tailings and of the other 4 samples surrounding the waste rock pile. This suggests that this silty clay, and possibly the silty clay at WR5 as indicated by high soluble magnesium sodium and potassium levels, may have originated from the original pit stripping operations. No sign of varving was noted at WR4 and WR5, as was very evident at WR1, WR2 and WR3. The radionuclide levels in all of the silty clay samples were very low, suggesting no significant radionuclide movement through them. The high variation in iron levels noted between samples may be partially explained by the tendency of iron to concentrate in the varves, and a differing ratio of winter and summer layers in the bulk sample analyzed.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Waste Rock

TH - TEST HOLE / TP-TEST PIT: TH

LOCATION ID: WR1

DRILLER / EXCAVATOR: D. Lush

SITE COORDINATES:

COMPLETION DATE: 84/06/23

N 465

TEST HOLE DIAMETER (m): 0.03

E 4555

TOTAL DEPTH (m) 1.00

GROUND ELEVATION (m) 69.0 ±

WELL OWNER NUTP

FILTER PACK LENGTH (m) 0.10

INSTALLER D. Lush

FORMATION OF COMPLETION: Silty Clay

INSTALLATION DATE 84/06/23

SEAL (END) DEPTH (m)

CASING ELEV. (m)

OPEN/SCREEN DEPTH (m) 0.90

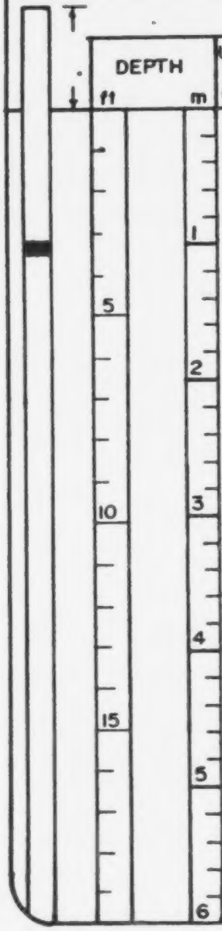
CASING LENGTH (m)

OPEN / SCREEN LENGTH (m) 0.10

CASING DIAMETER (m)

OPEN / SCREEN AREA (m²) 0.0094

LITHOLOGICAL SUMMARY



DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
						0 - 2 cm organic soil 2 - 100 cm varved silty clay some iron staining on varves.

FIGURE NO. 8.4

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Waste Rock
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: WR2
DRILLER / EXCAVATOR: D. Lush
SITE COORDINATES:
COMPLETION DATE: 85/06/23
N 465
TEST HOLE DIAMETER (m): 0.03
E 4727
TOTAL DEPTH (m) 1.00
GROUND ELEVATION (m) 72.8 ±

WELL OWNER NUTP
FILTER PACK LENGTH (m) 0.10
INSTALLER D. Lush
FORMATION OF COMPLETION: Silty Clay
INSTALLATION DATE 85/06/23
SEAL (END) DEPTH (m)
CASING ELEV. (m)
OPEN/SCREEN DEPTH (m) 0.90
CASING LENGTH (m)
OPEN / SCREEN LENGTH (m) 0.10
CASING DIAMETER (m)
OPEN / SCREEN AREA (m^2) 0.0094

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							0 - 2 cm organic soil.
							2 - 100 cm silty varved clay
	1		19.2				

FIGURE NO. 8.5

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Waste Rock
LOCATION ID: WR3
SITE COORDINATES:
N 622
E 4790
GROUND ELEVATION (m) 72.5 ±

TH - TEST HOLE / TP-TEST PIT: TH
DRILLER / EXCAVATOR: D. Lush
COMPLETION DATE: 85/06/23
TEST HOLE DIAMETER (m): 0.03
TOTAL DEPTH (m) 1.0

WELL OWNER NUTP
INSTALLER D. Lush
INSTALLATION DATE 85/06/23
CASING ELEV. (m)
CASING LENGTH (m)
CASING DIAMETER (m)

FILTER PACK LENGTH (m) 0.10
FORMATION OF COMPLETION: Silty clay
SEAL (END) DEPTH (m)
OPEN/SCREEN DEPTH (m) 0.90
OPEN / SCREEN LENGTH (m) 0.10
OPEN / SCREEN AREA (m^2) 0.0094

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							0 - 3 cm organic soil. 3 - 100 cm silty varved clay.
	1		28.2				

FIGURE NO. 8.6

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Waste Rock

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: WR4

DRILLER / EXCAVATOR: D. Lush

SITE COORDINATES:

COMPLETION DATE: 85/06/23

N 718

TEST HOLE DIAMETER (m): 0.03

E 4750

TOTAL DEPTH (m) 0.90

GROUND ELEVATION (m) 73.8 ±

WELL OWNER NUTP

FILTER PACK LENGTH (m) 0.10

INSTALLER D. Lush

FORMATION OF COMPLETION: Hard Packed Clay

INSTALLATION DATE 85/06/23

SEAL (END) DEPTH (m)

CASING ELEV. (m)

OPEN/SCREEN DEPTH (m) 0.80

CASING LENGTH (m)

OPEN / SCREEN LENGTH (m) 0.10

CASING DIAMETER (m)

OPEN / SCREEN AREA (m^2) 0.0094

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							Silty hard packed clay, some pinkish color - 0 - 90 cm.
	1		14.6				
5	2						
10	3						
	4						
15	5						
	6						

FIGURE NO. 8.7

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Waste Rock

TH - TEST HOLE / TP-TEST PIT: TH

LOCATION ID: WR5

DRILLER / EXCAVATOR: D. Lush

SITE COORDINATES:

N 750

E 5030

COMPLETION DATE: 85/06/23

TEST HOLE DIAMETER (m): 0.03

TOTAL DEPTH (m) 1.10

GROUND ELEVATION (m) 72 ±

WELL OWNER NUTP

FILTER PACK LENGTH (m) 0.10

INSTALLER D. Lush

FORMATION OF COMPLETION: Silty Clay

INSTALLATION DATE 85/06/23

SEAL (END) DEPTH (m)

CASING ELEV. (m)

OPEN/SCREEN DEPTH (m) 1.00

CASING LENGTH (m)

OPEN / SCREEN LENGTH (m) 0.10

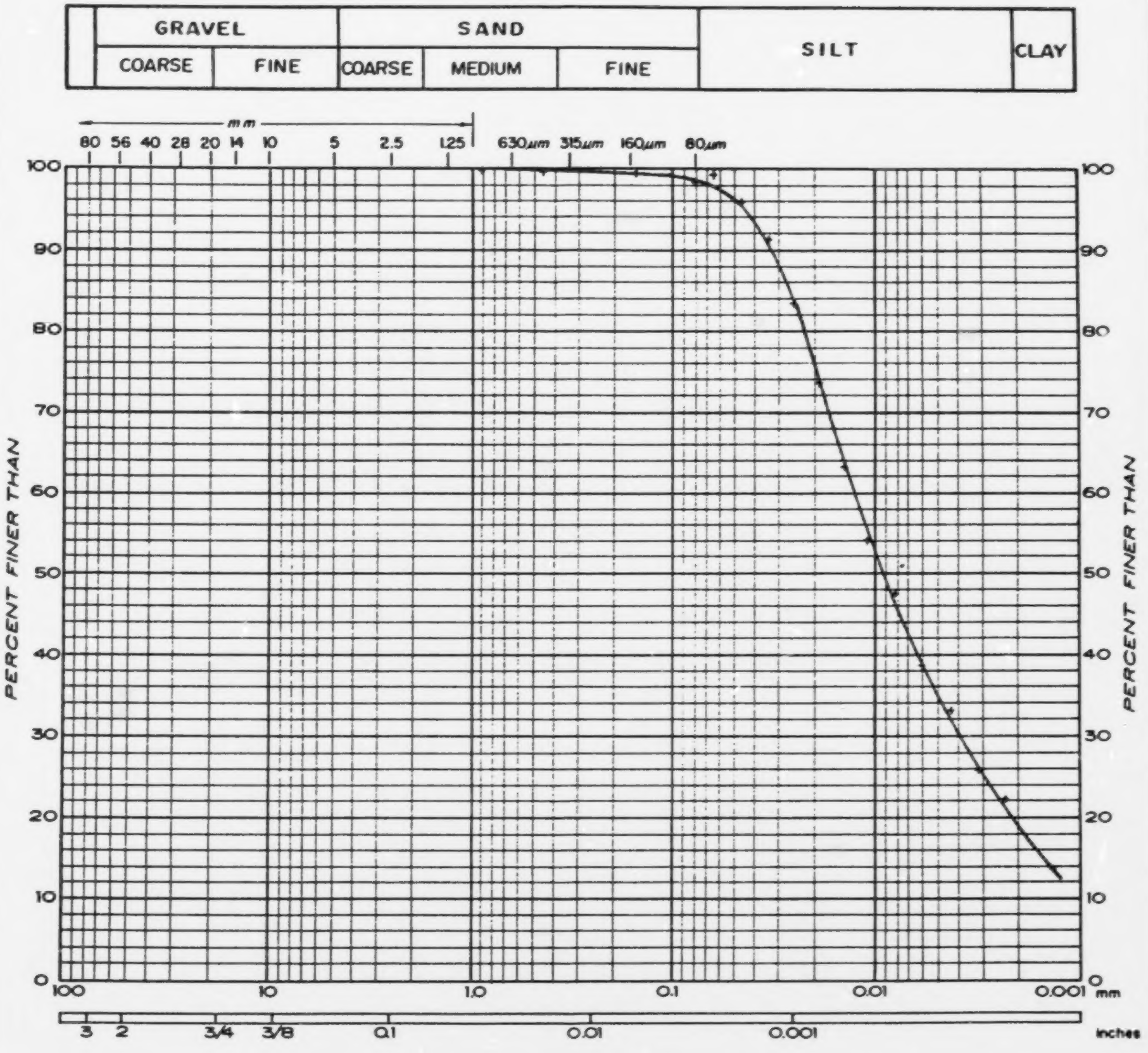
CASING DIAMETER (m)

OPEN / SCREEN AREA (m^2) 0.0094

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
							Very tight silty clay, some fracturing along what may be varves. Very thin 2 cm topsoil on surface.
	1		25.4				
5							
	2						
10	3						
	4						
15							
	5						
	6						

FIGURE NO. 8.8



NATIVE SOIL

D_{60} = 0.013 D_{30} = 0.004 D_{10} = -

REMARKS :

BBT Geotechnical Consultants Ltd.
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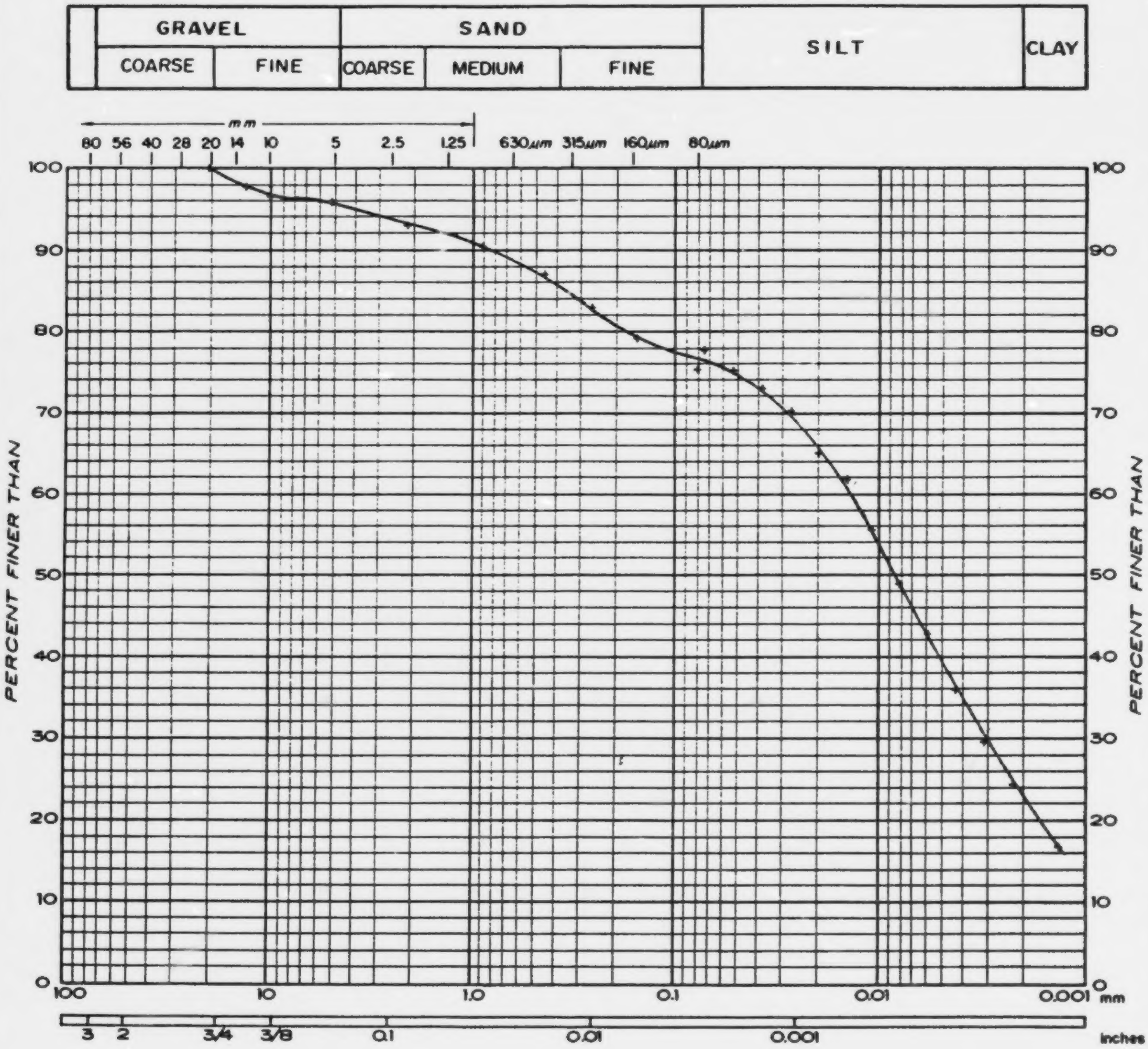
NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No.: WR3 Sample No.: 1
Depth :

FIGURE NO: 8.9



NATIVE SOIL

D_{60} = 0.014 D_{30} = 0.0032 D_{10} = ...

REMARKS : --

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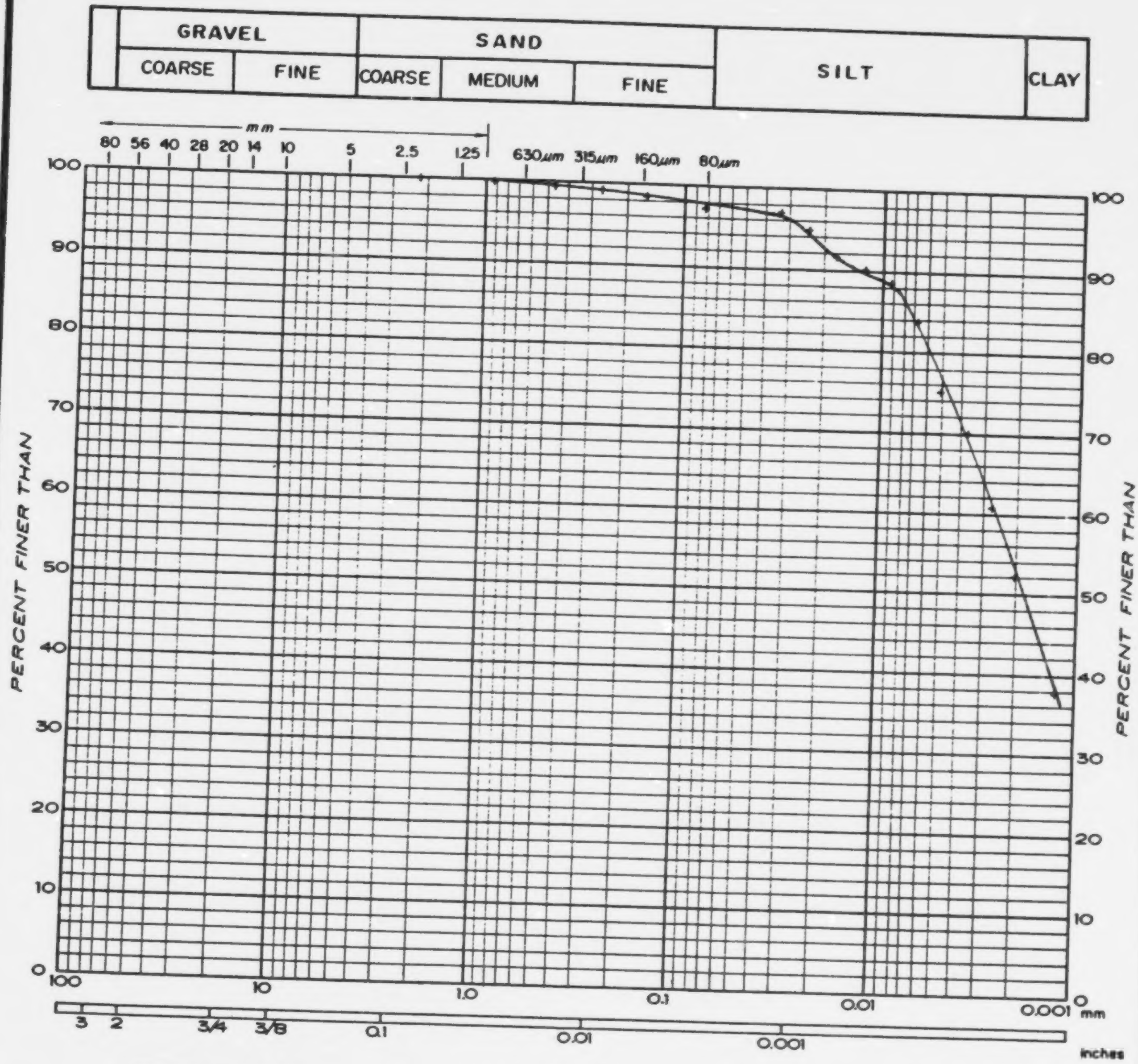
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No.: WR4 Sample No.: 1
Depth : ....

FIGURE NO.
8.10



NATIVE SOIL

D_{60} = 0.0025 D_{30} = – D_{10} = –

REMARKS :

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GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

GRAIN SIZE DISTRIBUTION

Test Hole No.: WR 5 Sample No.: 1
Depth :

FIGURE NO:
8.11

TABLE 8.7 TAILINGS SOLIDS ANALYSIS, WASTE ROCK PILE

Location	Waste Rock Pile Piezometer No. 1					Waste Rock Pile Piezometer No. 2				
Depth from Surface	1 m					1 m				
Parent Material	Sandy, silty clay, grey, varved					sandy, silty clay, grey, varved				
Field Code	WR Piezometer No. 1					WR Piezometer No. 2				
Date	85.06.23					85.06.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter										
pH of Leach Water										
IC Scan (Anions):										
Bromide	L 1	-	-	-	L 1	L 1	-	-	-	L 1
Chloride	L 24	-	-	-	L 24	22	-	-	-	22
Fluoride	1.9	-	-	-	1.9	1.8	-	-	-	1.8
O-Phosphate	L 2	-	-	-	L 2	L 2	-	-	-	L 2
Sulphate	1,130	-	-	-	1,130	160	-	-	-	160
Nitrate	0.2	-	-	-	0.2	0.2	-	-	-	0.2
Major Cations:										
Magnesium	94	3.11	2,930	97.0	3,020	50	1.62	3,040	98.4	3,090
Calcium	396	4.89	7,700	95.1	8,100	72	0.80	8,940	99.2	9,010
Iron	115	1.10	10,400	99.0	10,500	125	1.31	9,450	98.7	9,570
Manganese	16	12.7	110	87.3	126	1.0	0.61	163	99.4	164
Silica	1,270	0.17	742,000	99.9	743,000	1,470	0.26	563,000	99.8	564,000
Aluminum	281	0.59	47,700	99.3	48,000	176	0.85	20,500	99.0	20,700
Sodium	28	0.32	8,740	99.7	8,770	48	0.37	12,900	99.2	13,000
Potassium	48	0.31	15,300	99.7	15,300	93	0.47	19,900	99.5	20,000
Trace Cations:										
Strontium	1.2	0.50	241	99.6	242	0.8	0.33	238	99.6	239
Lead	0.2	1.64	12	98.4	12.2	0.5	3.23	15	96.8	15.5
Cobalt	L 0.2	-	4	100	4	L 0.2	-	5	100	5
Nickel	L 0.2	-	10	100	10	L 0.2	-	18	100	18
Zinc	L 0.2	-	15	100	15	L 0.2	-	38	100	38

TABLE 8.7   TAILINGS SOLIDS ANALYSIS, WASTE ROCK PILE

Location	Waste Rock Pile Piezometer No. 1					Waste Rock Pile Piezometer No. 2				
Depth from Surface	1 m					1 m				
Parent Material	Sandy, silty clay, grey, varved					sandy, silty clay, grey, varved				
Field Code	WR Piezometer No. 1					WR Piezometer No. 2				
Date	85.06.23					85.06.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	0.2	0.87	23	99.1	23	0.3	1.25	24	98.8	24
Copper	0.2	2.17	9	97.8	9.2	0.2	2.44	8	97.6	8.2
Cadmium	0.2	-	L 2	-	-	0.2	100	L 2	-	0.2
Barium	1.0	0.25	403	99.8	404	1.6	0.31	418	99.7	420
Vanadium	0.2	0.32	63	99.7	63	0.3	0.75	40	99.2	40
Titanium	8.9	0.40	2,220	99.6	2,230	7.8	1.89	405	98.1	413
Arsenic	0.02	1.18	1.7	98.8	1.7	0.02	3.23	0.6	96.8	0.62
Selenium	L 0.01	-	0.1	100	0.1	0.01	9.09	0.1	90.9	0.11
Molybdenum	L 0.2	-	2	100	2	0.2	9.09	2	90.9	2.2
Beryllium	L 0.1	-	L 1	-	-	0.1	-	L 1	-	-
Total Sulphur (%)										
Sum Anions										
Sum Cations										
Radionuclides										
Uranium (ug/g)	-	-	-	-	-	-	-	-	-	78.1
Thorium-230 (Bq/g)	-	-	-	-	-	-	-	-	-	0.09
Radium-226 (Bq/g)	-	-	-	-	-	-	-	-	-	0.90
Lead-210 (Bq/g)	-	-	-	-	-	-	-	-	-	L 0.04
Polonium-210 (Bq/g)	-	-	-	-	-	-	-	-	-	-
Radium-228 (Bq/g)	-	-	-	-	-	-	-	-	-	L 0.08
Thorium-232 (Bq/g)	-	-	-	-	-	-	-	-	-	0.04
Thorium-228 (Bq/g)	-	-	-	-	-	-	-	-	-	0.15
LOI %										

TABLE 8.7 TAILINGS SOLIDS ANALYSIS, WASTE ROCK PILE

Location	Waste Rock Pile Piezometer No. 3					Waste Rock Piezometer No. 4				
Depth from Surface	1 m					1 m				
Parent Material	Sandy, silty clay, grey, varved					Sandy, silty clay, grey				
Field Code	WR Piezometer No. 3					WR Piezometer No. 4				
Date	85.06.23					85.06.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter										
pH of Leach Water										
IC Scan (Anions):										
Bromide	0.8	-	-	-	0.8	L 1	-	-	-	L 1
Chloride	35	-	-	-	35	336	-	-	-	336
Fluoride	1.1	-	-	-	1.1	3.0	-	-	-	3.0
O-Phosphate	L 2	-	-	-	L 2	L 2	-	-	-	L 2
Sulphate	384	-	-	-	384	134	-	-	-	134
Nitrate	0.3	-	-	-	0.3	0.2	-	-	-	0.2
Major Cations:										
Magnesium	46	1.23	3,700	98.9	3,740	246	6.06	3,820	94.1	4,060
Calcium	85	1.12	7,520	98.8	7,610	86	1.10	7,760	98.9	7,850
Iron	39	0.28	13,800	99.7	13,800	656	4.52	13,800	95.2	14,500
Manganese	2.9	1.54	185	98.4	188	5.4	2.92	180	97.3	185
Silica	1,200	0.17	693,000	99.9	694,000	656	0.09	751,000	99.9	751,000
Aluminum	86	0.18	48,300	99.8	48,400	992	2.00	48,400	98.0	49,400
Sodium	28	0.25	11,300	99.7	11,300	93	0.78	11,800	99.2	11,900
Potassium	48	0.18	27,000	99.8	27,000	512	2.00	25,100	98.0	25,600
Trace Cations:										
Strontium	0.5	0.26	194	99.7	194	2.4	1.00	239	99.1	241
Lead	0.6	5.17	11	94.8	11.6	0.6	23.1	2	76.9	2.6
Cobalt	0.2	3.23	6	96.8	6.2	0.2	4.76	4	95.2	4.2
Nickel	0.5	2.86	17	97.1	17.5	0.8	4.76	16	95.2	16.8
Zinc	L 0.2	-	33	100	33	1.0	4.35	22	95.7	23

TABLE 8.7 TAILINGS SOLIDS ANALYSIS, WASTE ROCK PILE

Location	Waste Rock Pile Piezometer No. 3					Waste Rock Piezometer No. 4				
Depth from Surface	1 m					1 m				
Parent Material	Sandy, silty clay, grey, varved					Sandy, silty clay, grey				
Field Code	WR Piezometer No. 3					WR Piezometer No. 4				
Date	85.06.23					85.06.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	0.3	0.88	34	99.1	34	1.3	4.64	27	96.4	28
Copper	0.3	2.91	10	97.1	10.3	1.0	16.7	5	83.3	6.0
Cadmium	L 0.2	-	L 2	-	-	0.2	100	L 2	-	0.2
Barium	0.5	0.15	324	99.8	324	5.0	0.33	295	98.3	300
Vanadium	0.2	0.33	61	99.7	61	1.4	3.9	35	97.2	36
Titanium	5.3	0.23	2,350	99.8	2,350	34	1.59	2,110	98.6	2,140
Arsenic	0.02	1.54	1.3	98.5	1.3	0.1	5.00	1.9	95.0	2.0
Selenium	0.01	4.76	0.2	95.2	0.21	L 0.01	-	L 0.1	-	-
Molybdenum	L 0.2	-	2	100	2	0.2	100	L 2	-	0.2
Beryllium	0.08	7.41	1	92.6	1.08	L 0.1	-	1	100	1
Total Sulphur (%)										
Sum Anions										
Sum Cations										
Radionuclides										
Uranium (ug/g)	-	-	-	-	4.6	-	-	-	-	14.1
Thorium-230 (Bq/g)	-	-	-	-	0.08	-	-	-	-	0.18
Radium-226 (Bq/g)	-	-	-	-	0.07	-	-	-	-	0.16
Lead-210 (Bq/g)	-	-	-	-	L 0.04	-	-	-	-	0.08
Polonium-210 (Bq/g)	-	-	-	-	-	-	-	-	-	-
Radium-228 (Bq/g)	-	-	-	-	L 0.08	-	-	-	-	L 0.08
Thorium-232 (Bq/g)	-	-	-	-	0.06	-	-	-	-	0.07
Thorium-228 (Bq/g)	-	-	-	-	0.08	-	-	-	-	0.18
LOI %										

TABLE 8.7 TAILINGS SOLIDS ANALYSIS, WASTE ROCK PILE

Location	Waste Rock Pile Piezometer No. 3				
Depth from Surface	1 m				
Parent Material	Sandy, silty clay, grey				
Field Code	WR Piezometer No. 3				
Date	85.06.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Parameter					
pH of Leach Water					
IC Scan (Anions):					
Bromide	0.4	-	-	-	0.4
Chloride	8.8	-	-	-	8.8
Fluoride	1.7	-	-	-	1.7
O-Phosphate	L 1	-	-	-	L 1
Sulphate	168	-	-	-	168
Nitrate	0.1	-	-	-	0.1
Major Cations:					
Magnesium	240/264	5.05/5.22	4,750/4,800	95.2/94.9	4,990/5,060
Calcium	69/76	0.98/1.19	6,940/6,320	99.0/98.8	7,010/6,400
Iron	1,000/1,220	4.90/6.01	19,400/19,100	95.1/94.1	20,400/20,300
Manganese	8.0/8.9	2.95/3.28	263/262	97.0/96.7	271/271
Silica	8,640/7,440	1.23/1.02	656,000/725,000	93.2/99.0	704,000/732,000
Aluminum	1,580/1,890	2.68/3.20	57,400/57,100	97.3/96.8	59,000/59,000
Sodium	90/106	0.96/1.25	9,320/8,360	98.9/98.8	9,420/8,460
Potassium	488/552	1.67/1.96	28,700/27,600	98.2/97.9	29,200/28,200
Trace Cations:					
Strontium	2.0/2.1	0.88/0.96	225/216	99.1/99.1	227/218
Lead	1.0/1.4	6.67/14.9	14/8	93.3/85.1	15.0/9.4
Cobalt	0.3/0.4	4.76/7.40	6/5	95.2/92.6	6.3/5.4
Nickel	1.0/1.2	5.26/7.41	18/15	94.7/92.6	19.0/16.2
Zinc	1.4/1.8	3.59/5.29	38/32	97.4/94.1	39/34

TABLE 8.7 TAILINGS SOLIDS ANALYSIS, WASTE ROCK PILE

Location	Waste Rock Pile Piezometer No. 5				
Depth from Surface	1 m				
Parent Material	Sandy, silty clay, grey, varved				
Field Code	WR Piezometer No. 5				
Date	85.06.23				
	Water Leach (ug/g)	% of Total	Fusion (ug/g)	% of Total	Total (ug/g)
Chromium	1.6/1.9	4.21/5.94	36/30	94.7/93.8	38/32
Copper	1.0/1.2	8.33/11.8	11/9	91.7/88.2	12.0/10.2
Cadmium	0.2/0.3	100/100	L 2/L 2	-/-	0.2/0.3
Barium	5.9/6.5	2.00/2.32	289/274	98.0/97.9	295/280
Vanadium	1.8/2.0	3.91/6.25	44/30	95.7/93.8	46/32
Titanium	43/45	1.78/2.10	2,370/2,100	98.3/98.1	2,410/2,140
Arsenic	0.2/0.2	8.00/8.00	2.3/2.3	92.0/92.0	2.5/2.5
Selenium	L 0.004/L 0.004	-/-	L 0.1/L 0.1	-/-	-/-
Molybdenum	0.2/0.2	100/100	L 2/L 2	-/-	0.2/0.2
Beryllium	0.04/0.04	4.00/4.00	1/1	96.0/96.0	1.0/1.0
Total Sulphur (%)					
Sum Anions					
Sum Cations					
Radionuclides					
Uranium (ug/g)	-	-	-	-	4.1
Thorium-230 (Bq/g)	-	-	-	-	0.11
Radium-226 (Bq/g)	-	-	-	-	0.13
Lead-210 (Bq/g)	-	-	-	-	L 0.04
Polonium-210 (Bq/g)	-	-	-	-	-
Radium-228 (Bq/g)	-	-	-	-	L 0.08
Thorium-232 (Bq/g)	-	-	-	-	0.06
Thorium-228 (Bq/g)	-	-	-	-	0.25
LOI %					

8.8 WASTE ROCK PILE VEGETATION

Harms and Fraser, 1982 list the plant species found in the xeric shrub community on Gunnar mine wastes, along with frequency-abundance estimates based on interplant distance. Shrub abundance categories, according to Harms and Fraser, range from 'fairly frequent' (interplant distance approximately 5 m, e.g. Salix sp.) through 'locally frequent' (e.g. Rubus sp.) to 'occasional' (interplant distance approximately 10 m, e.g. Populus sp., Betula sp.). Fairly frequent herbaceous plants include grasses (e.g. Poa sp., Calamagrostis canadensis, Pucinellia nuttalliana, Hordeum jubatum), fireweed (Epilobium angustifolium) and bearberry (Arctostaphylos uva-ursi). The community has not changed greatly since the 1982 survey, although poplar shrubs were at least locally frequent based on the 1985 survey.

The waste rock community is the least productive of any described in the Gunnar area. The peak (August) biomass estimated from the 1985 survey was 18.66±21.37 gm dry weight/m^2. Photograph No. 8.3 shows the Xeric shrub community, low biomass.

PHOTOGRAPH NO. 8.3

Waste Rock Pile showing the Xeric shrub community, low biomass.

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Volume

9

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GUNNAR FIELD STUDY
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Volume 9
Eating Habits of the Local Population

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THE GUNNAR FIELD STUDY

The Gunnar Field Study consists of 10 volumes, each published separately. Volumes 2 to 10 are supplements to Volume 1, written as Appendices 1 to 9.

The 10 volumes are:

- Volume 1 - Summary Report
- Volume 2 - Test Procedures and QA/QC Program (Appendix 1)
- Volume 3 - Atmospheric Studies (Appendix 2)
- Volume 4 - Tailings Solids and Surround Soils (Appendix 3)
- Volume 5 - Groundwater (Appendix 4)
- Volume 6 - Surface Water (Appendix 5)
- Volume 7 - Biology (Appendix 6)
- Volume 8 - Waste Rock (Appendix 7)
- Volume 9 - Eating Habits of the Local Population (Appendix 8)
- Volume 10 - Permafrost (Appendix 9)

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EXECUTIVE SUMMARY

Eating Habits of the Local Population

Wild berries, including blueberries, cranberries, gooseberries and raspberries are consumed by Uranium City residents; however, picking is centered on Milliken Lake rather than the Gunnar site, and these species do not grow on Gunnar tailings. Cultivated vegetables, particularly potatoes, are grown for consumption in Uranium City but are not likely affected by radionuclide transport from Gunnar.

Terrestrial wildlife in the Gunnar area of potential importance in human diets, includes moose, caribou, rabbits, squirrels, grouse and ptarmigan. Fur bearing small game such as coyote, red fox, lynx, marten, mink, otter and weasel are taken by a local trapper but are not eaten. Other small game are sufficiently common in the Uranium City area that few hunters would travel as far as Gunnar to obtain them. Moose hunters may travel this far, but there are no moose-kill records from Gunnar. Caribou are infrequently sited on the Crackington Peninsula, the last sitings dating from the winter of 1979/80.

Fish were commercially harvested in the vicinity of the Gunnar site throughout the 1960's and 1970's; a fish processing plant at Gunnar ceased operation in 1980. Catch statistics indicate that whitefish, lake trout and suckers were the main species harvested. Sport fishing continues in the area, for trout and pike in the vicinity of Langley Bay. The sport fishery harvest is unknown, but represents a potentially significant human exposure pathway.

Statistics on eating habits of Uranium City residents, from Gillis (1975) prior to the Beaverlodge mine closure, indicate that wild meat was consumed on average 0.8 times/week, fish 1.0 times/week, vegetables 10.3 times/week and fruit 10.9 times/week. Wild meat and fish consumption may increase after Beaverlodge decommissioning with reduced access to commercial food supplies.

VOLUME 9

Eating Habits of the Local Population

9.0 EATING HABITS OF THE LOCAL POPULATION

9.1 Introduction

The tailings from the Gunnar tailings may pose a potential danger for humans who consume wild meat, berries or vegetables harvested in the vicinity of the site. To substantiate this possibility, it is necessary to analyze the eating habits of the local residents in terms of the type of meat and plant material they consume, the quantity consumed and the locations from which the species are harvested.

The location of the Gunnar Field on the southwest of the Crackingstone Peninsula means that both land and water life should be considered. Consequently, the study deals with terrestrial wildlife, such as caribou, moose, rabbits, grouse and other commonly consumed species, as well as fish and waterfowl. Gardening, too, is examined and berry picking is identified.

9.2 Limitations

Documented information on the eating habits of the local residents and on terrestrial and aquatic wildlife in the vicinity of the Gunnar site was limited; therefore, regional statistical data from the surrounding area were used in conjunction with information obtained from interviews with key individuals. Personal interviews were carried out with selected knowledgeable individuals from Uranium City and from northern government agencies. The major limitations in this portion of the study were:

1. insufficient published information on natural food consumption rates and wildlife statistics for the Gunnar site; and
2. insufficient budget to carry out an extensive survey of hunters, trappers, fishermen and local residents.

9.3 Methodology

Early in the study, publications from the following agencies were obtained:

- Fisheries Branch (Saskatchewan),
- Saskatchewan Research Council,
- Department of Parks and Renewable Resources,
- the Department of Northern Saskatchewan, and
- Department of National Health and Welfare.

As well, personal interviews were conducted with:

- Mr. George Bihun, the present Uranium City Conservation Officer who has been a resident of Uranium City for some time;
- Mr. Ryan Mulligan, Uranium City Conservation Officer from 1981 to 1984;
- Mr. Tim Trottier, Wildlife Ecologist, Department of Parks and Renewable Resources, La Ronge (Mr. Trottier is a caribou specialist and is familiar with the Gunnar site);
- Mr. Ed Kowal, Wildlife Ecologist, Department of Parks and Renewable Resources; Prince Albert (Mr. Kowal is a moose specialist); and
- Mr. Bruce Smith, representative from the Freshwater Fish Marketing Corporation in La Ronge and the last operator of the Crackingstone Fish Plant.

9.4 Eating Habits of the Local Residents

According to Mr. R. Mulligan and Mr. G. Bihun, Uranium City residents represent the major group of individuals using the Crackingstone Peninsula and the adjacent waters for food consumption. The "local population" in terms of the Gunnar tailing study is, therefore, the Uranium City residents.

The population of Uranium City has undergone significant decrease since the closure of the Beaverlodge Mine in December 1981. Its population has dropped from 2,479 people in 1981 to 455 in 1984 and less than 100 in 1985.

Unfortunately, statistics on northern eating habits in Uranium City were gathered prior to the 1981 closure of Eldorado Nuclear Ltd.'s mine and are, therefore, limited in their usefulness. However, relevant aspects of a 1975 report prepared for the Department of Northern Saskatchewan by Debra Gillis are noteworthy.

In the 1975 study, communities from throughout northern Saskatchewan were surveyed and four "residence code" groups were identified according to food availability, the number and types of stores, the food transportation system and the availability of nutrition education through the media or health centre. Table 9.1 outlines the four groups.

Statistics were gathered on the frequency of food consumption. Table 9.2 indicates how often individuals in the four residence codes consumed wild meat. Uranium City residents (residence code 4) ate wild meat an average of 0.8 times/week in the past. This indicates that wild meat was eaten almost one day out of every week. This statistic, however, is probably inaccurate at the present time as transportation and, therefore, the availability of different foods is more restricted now due to diminished winter road transportation and decreased economic activity in the area.

Unfortunately, none of the four residence codes accurately describes the present circumstances in Uranium City. The statistic averaged for northern Saskatchewan as a whole, however, may provide a more useful though broad guideline. This statistic indicates that northern residents eat wild meat an average of 2.8 times per week (Gillis, 1975).

The consumption of fish is slightly lower; one time per week for Uranium City residents in the past, including both commercial and locally caught produce. This statistic may be higher at present considering the economic changes and reduced availability of food in the community.

TABLE 9.1: COMMUNITIES DESIGNATED FOR EACH RESIDENCE CODE BASED ON THE CHARACTERISTICS OF THE COMMUNITY

Residence Code	Community	Rationale for Grouping
1	Michel Village	o 0 or 1 store
	Stony Rapids	o air access for food supplies
	Pinehouse	o health centre or visiting nurse service
		o no media service
2	Turnor Lake	o 1 or more stores
	Sandy Bay	o road access to food supplies
	Cumberland House	o health centre and limited media service
	Bearwall	
3	Ile a la Crosse	o road access to food supplies
	La Loche	o 1 or more stores
	Greenlake	o health centre and limited media service
4	Uranium City	o excellent access to food supplies
	La Ronge	o good media and health facilities
	Creighton	o good variety in number and types of stores

Source: Gillis, D. 1975. Department of Northern Saskatchewan. Nutrition in Northern Saskatchewan.

TABLE 9.2: RELATIVE FREQUENCY OF WEEKLY CONSUMPTION OF WILD MEAT

	Residence Code			
Food Group	1	2	3	4
Wild Meat	6.4	1.7	5.2	0.8
Fish*	-	-	-	1.0
Vegetables*	-	-	-	10.3
Fruit*	-	-	-	10.9

Source: Gillis, D. 1975. Department of Northern Saskatchewan. Nutrition in Northern Saskatchewan.

* Fish, vegetables and fruit include store-bought produce, as well as wild and home-grown produce. Proportions vary with availability of commercial food supplies.

Of the animals hunted for meat, moose was consumed more frequently than caribou or rabbit (Gillis, 1975). This information is substantiated in February 1985 by Mr. G. Bihun, the Conservation Officer for Uranium City, who has indicated that moose meat is readily consumed, while rabbit and grouse are less commonly eaten by Uranium City residents. Caribou consumption is very sporadic because caribou are often inaccessible due to varying yearly migration paths.

According to the 1975 nutrition report (Gillis, 1975), vegetables and fruit were generally consumed at frequencies of 10.3 times per week and 10.9 times per week respectively, with potatoes representing a major part of the vegetable consumption and berries representing a very minor portion of the total weekly fruit consumption. Consumption of commercial produce is included in these figures. Gillis (1975) estimates that only 3% of northern Saskatchewan residents obtain their food entirely from wild sources, and that 25% obtain half of their food from the wild.

Caribou

According to Mr. Tim Trottier, use of the peninsula for caribou hunting has been negligible in the past several years (pers. comm., February 1985). Mr. Ryan Mulligan suggests that the adverse terrain on the uncleared portions of the peninsula would preclude most hunting activity in the area near Gunnar and he is unaware of any caribou harvested in this area in the past (pers. comm., February 1985).

Moose

Statistics are unavailable for the moose harvest from the Crackingstone Peninsula or the surrounding area as survey blocks do not extend this far north.

Mr. G. Bihun indicates that an average of 20 moose licenses were purchased in each of the past two years. Of these hunters, Mr. Bihun suggests that only one to two individuals have hunted on the peninsula and neither he nor Mr. R. Mulligan recall any moose actually being harvested from that region.

Small Game

According to Mr. R. Mulligan (Conservation Officer, Uranium City, 1981-1984), rabbit meat was not consumed much by Uranium City residents while he resided there. This could have been due to the low rabbit population during those years as Mr. G. Bihun suggests that rabbits are eaten by the town residents, but most are harvested from the immediate vicinity of Uranium City. In his estimation, few individuals would travel the distance to Gunnar for rabbit hunting.

No statistics are available on the number of grouse or ptarmigan hunted and consumed by the local population near the Gunnar site. Mr. R. Mulligan, however, indicated that ptarmigan were hunted quite heavily in the years he resided at Uranium City. Spruce grouse received considerably less hunting pressure and ruffed grouse, minimal pressure. Ptarmigan were generally hunted near plowed roads where they forage in the winter. Mr. Mulligan suggests that there are probably no ptarmigan harvested from the Gunnar areas.

Mr. Bihun suggests that local trappers may hunt rabbits, grouse, squirrels and ptarmigan for food while checking traplines. However, only one trapper, Mr. D. Augier, works the Gunnar area.

Waterfowl

According to Mr. R. Mulligan, hunting for waterfowl is negligible in the Gunnar/Uranium City area.

Commercial Fishery

Commercial fishing on Lake Athabasca began in the 1920's and has continued intermittently through to 1985. For the purpose of this report, production figures over the past 20 years have been compiled. They are detailed in Table 9.3. Those production values identified for the Crackingstone fishery are relevant as they deal with the region

TABLE 9.3: COMMERCIAL FISH PRODUCTION FROM THE SASKATCHEWAN PORTION OF LAKE ATHABASCA IN MARKET WEIGHT (kg) FOR 1964 TO 1985

Commercial Fish Production for the East End and Cracking Stone* Zones

Year	Whitefish			Trout			Pickerel			Pike			Other			Total		
	Ath	East End	Cr. Stone	Ath	East End	Cr. Stone	Ath	East End	Cr. Stone	Ath	East End	Cr. Stone	Ath	East End	Cr. Stone	Ath	East End	Cr. Stone
1964	291247	50314	240933	250692	91863	158829	14353	6665	7688	20822	10090	10732				577114	156932	418182
1965	421515	32911	383604	199658	98114	101544	16134	1033	15091	16908	3616	13292				654205	140674	513531
1966	400305	45155	355150	192015	89305	102710	6736	603	6133	12230	2229	10001				611286	137292	473994
1967	311828	30953	280875	119706	52872	66834	13413	307	13106	7348	808	6540				452295	84940	367355
1968	208179	21365	186814	119622	30536	89086	28141	547	27594	24200	2944	21256				380142	55392	324750
1969	295667	-	295667	77992	-	77992	16915	-	16915	21050	-	21050				411624	-	411624
1970	289507	19022	270485	167906	73492	94414	61687	1850	59837	41747	1679	40068				560847	96043	464804
1971	189825	67532	122293	118022	56732	61290	41794	1597	40197	25659	9145	16514				375300	135006	240294
1972	225715	106662	119053	73429	41317	32112	35473	1014	34459	26173	13932	12241				360790	162925	197865
1973	322442	79335	243107	94406	28227	66179	5876	568	5308	8809	4652	4157				431533	112782	318751
1974	92763	8745	84018	47843	6622	41221	1543	300	1243	5444	656	4788	9913			157506*	16323	131270
1975	168567			53170			2462			3139						227338		
1976	133495			100268			7605			4120						245488		
1977	188477			69194			5779			3760			6924			274134		
1978	14852			50766			1139			1001						67758		
1979	20114			100869			1059			8797						130839		
1980	54558			152611			7058			2607			2784			219618		
1981	-			15717			3604			264			455			20040		
1982	34			4042			1482			66			-			5624		
1983	113			1317			-			23			357			1810		
1984																		

* Crackingstone zone includes the central, south and west zones.

Source: Fisheries Branch, DPRR. Commercial Production Report, Athabasca Lake. Annual Data Sheet.

Chen, M.Y. 1973, 1974. Fisheries Branch, DPRR. Technical Reports, Sampling of Athabasca Commercial Fishery.

in which the Gunnar Tailings Area is located. Unfortunately, such statistics are only available up to 1974 after which statistics from Lake Athabasca as a whole were tabulated. Fisheries statistics for the last ten years are, therefore, regional in nature. The Athabasca fishery was divided into several districts up until 1974. These districts included the east end, central zone, west end and south shore. The Crackingstone fishery includes the three latter districts. The central zone was further subdivided into parcels or zones. Zone D, in particular, took in the waters off the Crackingstone Peninsula. Tables 9.4 and 9.5 indicate the percentage round weight of production recorded in the Crackingstone fishery in 1973 and 1974. Zone D figures show that over half of the whitefish and lake trout production in the central zone came from the area surrounding the Crackingstone Peninsula (Zone D) in 1973 and 1974. The northern pike catch was largely from the Crackingstone Peninsula area as well, while walleye was largely absent within the zone.

In the past, the Athabasca fishery used a fish processing plant located in the Gunnar site where an abandoned warehouse was converted into a fish processing plant. In the late 1970's, 30 to 40 staff and plant workers were employed at the plant, and an equivalent number of fishermen lived at the site with their families (pers. comm., D. Smith, Freshwater Fish Corp., March 1985). The plant was plagued with financial difficulties and had to be subsidized by the Department of Indian Affairs and the Department of Northern Saskatchewan in order to operate during that time. 1980 was the last year of operation of the Gunnar fish plant (pers. comm., B. Smith).

At present, no commercial fishery is operated in the Crackingstone or Fond du Lac zones. This is due largely to the lack of equipment and facilities for summer fishing and the local inexperience and poor equipment for winter fishing (pers. comm., B. Smith). A fishery has been established on the south shore of Lake Athabasca by Beauval and Buffalo Narrows fishermen, and is deemed to be quite successful (pers. comm., G. Bihun). A major incentive for the continuation of this fishery is the current (1984) high price for lake trout (pers. comm., B. Smith).

TABLE 9.4: COMMERCIAL PRODUCTION OF EACH SPECIES FROM CRACKINGSTONE REGION OF LAKE ATHABASCA IN 1973 AS EXPRESSED IN PERCENTAGE OF ROUGH WEIGHT IN VARIOUS LOCALITIES*

Locality	Whitefish	Lake Trout	Walleye	Pike	All Species lb.	All Species %
Central	64.48	59.15	22.61	50.28	187,045	62.60
A	1.79	1.48	-	3.62	5,096	1.70
B	3.90	0.96	-	0.90	8,977	3.00
C	1.36	-	-	-	2,843	0.95
D	37.26	37.65	0.35	22.88	110,740	37.06
E	20.06	19.00	22.26	22.88	59,103	19.78
F	0.11	0.06	-	-	296	0.10
South	12.16	18.96	8.29	3.47	41,984	14.05
West	23.36	21.89	69.10	46.25	69,756	23.35
All Areas:	208,496 (100%)	86,575 (100%)	1,725 (100%)	1,989 (100%)	298,785	100
%	69.78	29.98	0.58	0.66	100	

* Based on recorded catch for the periods of sampling only 298,785 lb.

Source: Chen, M.Y. 1973. Fisheries Research Program, Saskatchewan Department of Natural Resources. Lake Athabasca Commercial Fishery, 1973. Fisheries Technical Report.

TABLE 9.5: COMMERCIAL PRODUCTION FROM CRACKINGSTONE FISHERY IN 1974, AS EXPRESSED IN PERCENT ROUGH WEIGHT IN VARIOUS LOCALITIES[1]

				Sub Total			All Species	
Locality	Whitefish	Trout	Pike	lb.	%	Sucker	lb.	%
Central	94.4	89.0	99.0	226,790	92.2	93.8	248,755	92.3
B	2.8	9.7	9.5	14,187	5.8	1.2	14.467	5.4
D	50.3	48.8	84.7	123,349	50.1	70.3	139,799	51.9
E	16.6	16.8	0.3	40,418	16.4	19.8	45,047	16.2
F	18.9	9.5	3.7	36,308	14.8	1.8	36,741	13.6
G	5.6	3.1	0.9	11,061	4.5	0.7	11,234	4.2
H	0.2	1.1	0	1,467	0.6	0	1,467	0.5
Western	5.6	11.0	1.0	19,021	7.8	6.2	20,652	7.7
Total (lb)	140,444	102,292	3,255	245,991		23,416	269,407	
%*	57.1	41.6	1.3	100				
%**	52.1	38.0	1.2	(91.3)		8.7	100	

[1] Based on recorded catch for the period of sampling only, 269,407 lb.

* Not including white suckers.

** Including white suckers.

Source: Chen, M.Y. 1974. Fisheries Research Program, Saskatchewan Tourism and Renewable Resources. Sampling of Athabasca Commercial Fishery, 1974. Fisheries Technical Report 74-10.

Sport Fishing

No statistics have been compiled for sport fishing near the Gunnar Field. Mr. G. Bihun, however, indicates that there is a significant amount of trout fishing done at the mouth of Gruchy Bay which is located adjacent to Langley Bay. Mr. R. Mulligan also indicated that, during his appointment at Uranium City (1981-1984), numerous pike were fished in Langley Bay when other fishing activity was slow. There was also a popular fishing spot in the bay south of Gunnar on Hilyard Island. Any specific information on exact volumes or uses of such harvested fish is unknown.

Gardening

Vegetable gardens are common at Uranium City and yields can be high if the soil is improved and maintained. No gardens exist at the Gunnar site as no residents live there at present (pers. comm., G. Bihun). There may have been gardens at the site when the fish processing plant was in operation.

Gardens in Uranium City average between 9 m x 9 m to approximately 9 m x 18 m, with potatoes often occupying approximately half the garden (pers. comm., R. Mulligan). Additional crops experiencing high yields include peas, carrots, cauliflower and beets.

Berry Picking

Berry picking is a popular summer activity in the Uranium City area. It is mainly focused around Milliken Lake where blueberries, cranberries and gooseberries are commonly picked (pers. comm., G. Bihun and R. Mulligan). Raspberries are picked along road allowances and trails. R. Mulligan indicated that raspberries were picked at the old National Exploration site on the shores of Donaldson Lake and G. Bihun suggested that the Gunnar site and adjacent trails could be popular for raspberry picking, but he was not certain of this.

9.5 Summary

The pertinent points obtained from the study results are summarized below:

- Uranium City residents consume wild meat approximately 0.8 to 2.8 times per week. Moose is generally the most popular type of wild red meat consumed.
- Fish is eaten at least once per week.
- Local potatoes are a commonly eaten vegetable.
- Wild berries make up a small portion of the local population's diet.
- Very few wildlife species are hunted on the Crackingstone Peninsula due to inaccessibility and adverse terrain. According to the Conservation Officers who have worked in the area, extremely few or no moose have been harvested from the peninsula and caribou have not migrated to such a southerly extent since 1979-80.
- Small animals that supplement local diets (i.e., rabbits, ptarmigan, grouse) are hunted in close proximity to Uranium City, with the exception of ptarmigan. These animals have demonstrated low densities in the past three to four years. Ptarmigan generally congregate near plowed roads in winter and are, therefore, not thought to be common near the Gunnar site.
- Commercial fishing is presently dormant in the Uranium City area, although one or two fishermen have been known to fish commercially on occasion and sell to the local residents.
- Significant sport fishing is undertaken in and near Langley Bay.
- Many local gardens are planted at Uranium City with potatoes being a prominent crop.
- Berries are generally picked relatively close to Uranium City; however, there is a possibility that the Gunnar site could be used for this activity.

9.6 Data Deficiencies

Data deficiencies occur in a number of areas within this portion of the tailings study. The major data deficiencies include the following:

- no current information on food consumption rates exist for the present population of Uranium City; statistics taken from prior to the closure of the Beaverlodge Mine are likely understated when viewed in terms of the present circumstances in the community;
- accurate documented statistics concerning the densities of wildlife at Gunnar and the harvests from the surrounding area are non-existent; in several cases, the conservation officers are unsure or unaware of the number of animals in the area and the actual number of animals being harvested; and
- the most significant data deficiency exists in the lack of information on sport fishing; it is known that fish are being caught in and near Langley Bay where tailings are present, but the amount of fish caught and the ultimate useage of these fish is unknown.

9.7 Conclusions and Recommendations

Based on the study results, terrestrial wildlife (moose, caribou, rabbits, ptarmigan and grouse) is relatively sparce in the vicinity of the Gunnar Field and, according to conservation officers, few of these species have been harvested from the Crackingstone Peninsula. This information, in conjunction with the reported low consumption rates of rabbits and caribou, suggests that any potentially contaminated wild meat from the species examined in this section has not been consumed by the local population.

Fish, on the other hand, is consumed at least once per week and is generally supplied by local fishermen who may use the waters in or near Langley Bay. The probability of local residents consuming contaminated fish is, therefore, significantly higher, though this cannot yet be substantiated. This concern should be explored further through a more thorough survey of local fishermen.

While the consumption of wild fish, game and berries is likely to increase with reduction of commercial meat supplies, the need to venture to Gunnar for hunting and berry picking should also decline. Game and berries near Uranium City may be sufficiently abundant to meet the needs of the reduced population.

Gardening is done at Uranium City and there is little risk of contamination from the Gunnar tailings.

Wild berry consumption rates are low in terms of the total weekly fruit intake of northern residents. Nevertheless, there is a possibility that raspberries may be picked at Gunnar. Confirmation of this possibility could be obtained from the local trapper or from a cabin owner near Langley Bay.

It is recommended that additional information be obtained on sport fishing and berry picking at and near the Gunnar site as there is significant reason to believe that potentially contaminated food is being consumed. While interviewing local residents on these subjects, verification of the reported terrestrial wildlife information could be ascertained and additional information on eating habits could also be obtained.

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9.9 Personal Communications

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Volume

10

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CONTRACT REPORT NUMBER: OSQ84-00195
VOLUME 10
APPENDIX 9

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
CONTRACT NO. 15SQ.2341-4-1674X
VOLUME 10 - APPENDIX 9
PERMAFROST

Prepared For:
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CONCORD SCIENTIFIC CORPORATION

105 pp

BBT PROJECT NO. S84-1750

MARCH 31, 1986

EXECUTIVE SUMMARY

A portion of the Gunnar Main Tailings area was characterized by a number of mounds which extended up to 1 m above the tailings pile surface and which were several meters across. These mounds tended to be located in the low-lying portions of the tailings adjacent to standing water. Test Hole No. N2A was drilled through one of these mounds in the November campaign and encountered ground ice at a depth well below what would reasonably be anticipated for seasonal frost penetration. It was therefore concluded that discontinuous permafrost was present and the theory was put forward that these mounds were similar in origin to palsas or peat mounds.

The Scientific Authority authorized additional investigative work to learn more about the extent and conditions contributing to the permafrost. The extent of additional work was dictated by logistical and/or budget constraints, and consisted of the following:

1) Additional drilling to identify areas of permanently frozen tailings within or adjacent to the mounds.
2) An electromagnetic survey to attempt to determine areas of permanently frozen tailings by means of conductance techniques.
3) Installation of thermistor strings to measure ground temperatures at selected locations during the summer of 1985.
4) Snow depth measurements in the winter of 1985.

The EM survey was inconclusive in determining the presence of ground ice due to the high conductivity of the saturated tailings. The snow depth in March varied up to 1 m in the hollows between mounds with the top of the mounds being clear. Permafrost was found in 3 test holes which were drilled through mounds and generally was absent in the areas between the mounds. The thermistor readings confirmed the presence of permafrost in the above referenced holes.

The tailings in the area where the mounds and permafrost were found, generally were fine and silty with a permeability in the order of 1E-04 to 1E-06 cm/sec. Also, the water table in this area was very high and near ground surface.

The investigation confirmed the presence of permafrost and the palsa or mound theory appears valid. Proximity to the water table appeared to be a prerequisite for the mounds to form, and the absence of snow cover on top of the mounds no doubt promotes frost penetration. The information collected was not as extensive as hoped due to a less than desired number of test holes and the inconclusiveness of the EM survey. Therefore, although the concept of promoting permanently frozen tailings appears to have merit, the findings of this investigation were not conclusive enough to provide recommendations on the unique combination of conditions necessary for this to occur.

THE GUNNAR FIELD STUDY

The Gunnar Field Study consists of 10 volumes, each published separately. Volumes 2 to 10 are supplements to Volume 1, written as Appendices 1 to 9.

The 10 volumes are:

- Volume 1 - Summary Report
- Volume 2 - Test Procedures and QA/QC Program (Appendix 1)
- Volume 3 - Atmospheric Studies (Appendix 2)
- Volume 4 - Tailings Solids and Surrounding Soils (Appendix 3)
- Volume 5 - Groundwater (Appendix 4)
- Volume 6 - Surface Water (Appendix 5)
- Volume 7 - Biology (Appendix 6)
- Volume 8 - Waste Rock (Appendix 7)
- Volume 9 - Eating Habits of Local Population (Appendix 8)
- Volume 10 - Permafrost (Appendix 9)

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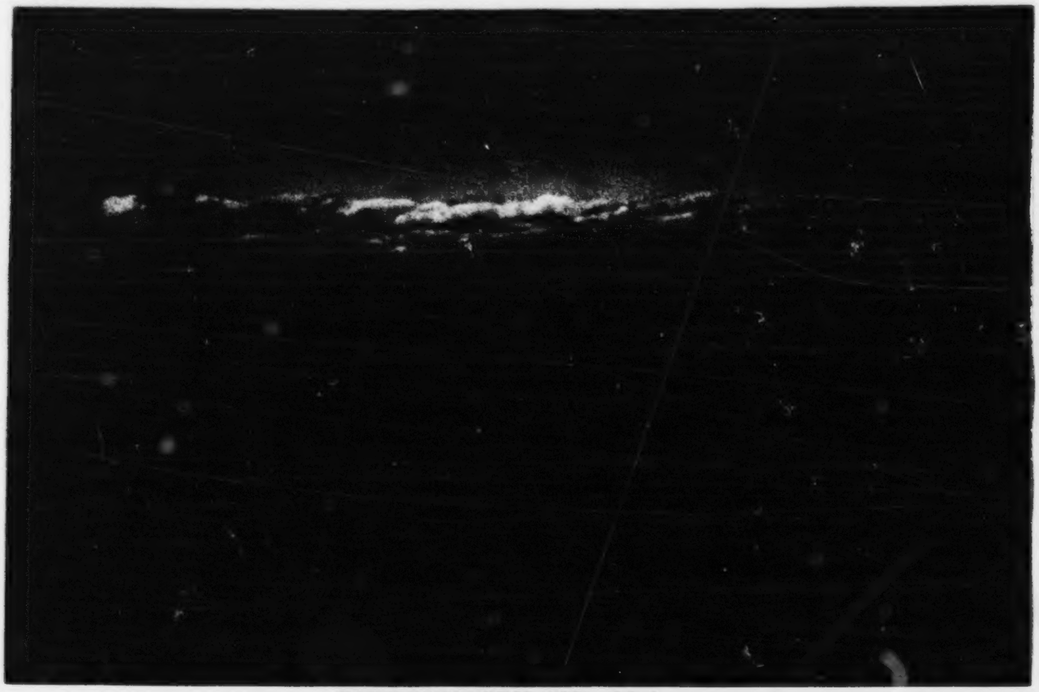
10.0 INTRODUCTION

During the initial drilling program in December 1984, frozen tailings were encountered at depths of 3.6 to 4.9 m in Test Hole No. N2A on Gunnar Main. The frozen tailings at this depth could not reasonably be attributed to seasonal frost penetration and appeared to be relict frost from conditions of deposition or permanently frozen tailings resulting from surface heat loss. The Gunnar Mine is located in the discontinuous permafrost zone, as are all Northern Saskatchewan uranium tailings. It was subsequently decided by the Scientific Authority that field measurements in addition to those presented in the original terms of reference would be of benefit to determine the extent of the frozen tailings.

The Gunnar Main Tailings area had an overall relief of approximately 10 m. The topographic high was located in the south portion of the tailings basin at the old spigot location, while the topographic lows were situated along the north and easterly portion of the basin. Surface water was ponded in some of the topographic lows (see Photograph Nos. 10.1 and 10.2). An interesting feature of the lower topography of the Gunnar Main Tailings was the presence of a number of ellipsoid-shaped elevated mounds (Photograph No. 10.1). These mounds extended approximately 1.0 m above the surrounding terrain and were several meters across. Test Hole No. N2A which encountered frost at depth was located on one of these mounds and it therefore appeared likely that the mounds were related to permanently frozen ground.

One theory proposed for the origin of these mounds was that they were similar to peat mounds or palsas which form in peatlands in the north. One consistent feature of their occurrence on the Gunnar project appeared to be that they formed adjacent to standing water in low-lying areas of the tailings where the water table was near ground surface. A readily available source of water seemed to be necessary for their formation. Figure No. 10.1 shows a schematic representation of how these mounds possibly form. This representation was used to provide direction for the investigative program which followed.



PHOTOGRAPH NO. 10.1

Lower area of Gunnar Main showing "frost heaves" adjacent to the ponded water (August 1985).

PHOTOGRAPH NO. 10.2

Installation at GM2 on Gunnar Main with ponded water in background. The monitor wells on the left are in frozen ground, while those on the right are not (August 1985).

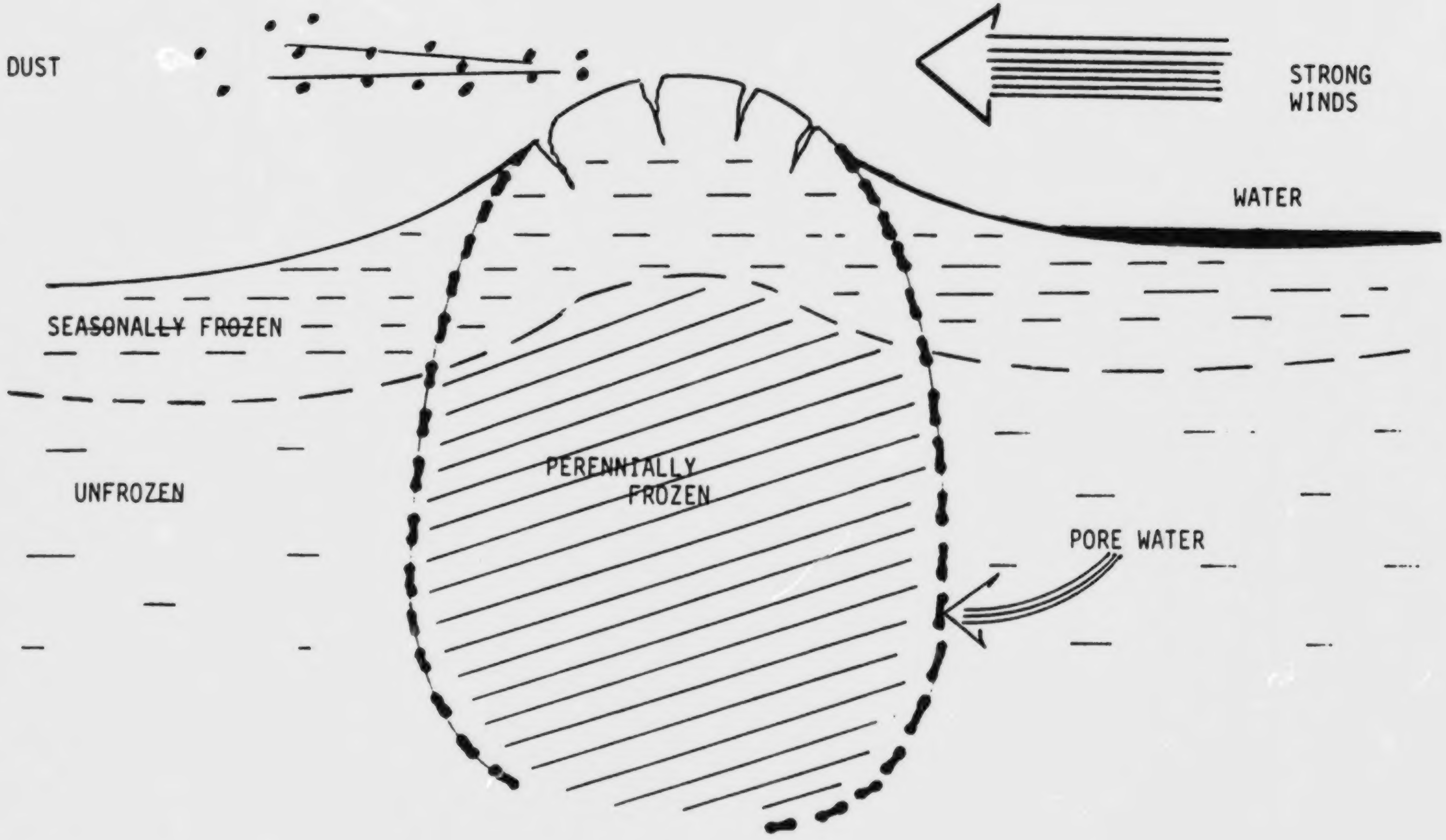

DUST
STRONG WINDS
WATER
SEASONALLY FROZEN
UNFROZEN
PERENNIALLY FROZEN
PORE WATER

FIGURE NO. 10.1 POSSIBLE SCHEMATIC REPRESENTATION OF FROST HEAVES ON GUNNAR MAIN

The additional field measurements authorized by the Scientific Authority consisted of the following:

1) Additional drilling to identify areas of permanently frozen tailings within or adjacent to the mounds.
2) An electromagnetic survey to attempt to determine areas of permanently frozen tailings by means of conductance techniques.
3) Installation of thermistor strings to measure ground temperatures at selected locations during the summer of 1985.
4) Snow depth measurements in the winter of 1985.

The additional measurements were to be made on a portion of the Gunnar Main Tailings only.

This appendix describes the testing plan, the procedures, and the results of these additional field measurements. The bulk of the additional installations and measurements were made in March 1985, with thermistor readings taken during the summer of 1985. The EM survey was conducted under subcontract to Mr. P. Pehme, a private consultant specializing in this field. Mr. Pehme provided a report on the survey which is included in its entirety as Section 10.5 of this appendix.

10.1 TESTING PLAN

10.1.1 Methods of Testing

The testing methods selected were a combination of thermistor strings, visual observations of drill cuttings, measurements of snow depths and an electromagnetic (EM) survey of a selected portion of Gunnar Main. These methods were deemed to be most compatible with the logistical support available to the project.

10.1.2 Sampling Locations

A series of potential thermistor string locations were selected with the intent of providing data in both frozen and non-frozen areas of the tailings for correlation with the EM survey. Unfortunately, due to a combination of very heavy snow cover impeding site access and drilling equipment malfunctions, it was not possible to complete all of the thermistor installations exactly as planned. A total of 9 thermistor strings were installed at locations as shown on Figure No. 10.2 with the notation "Th".

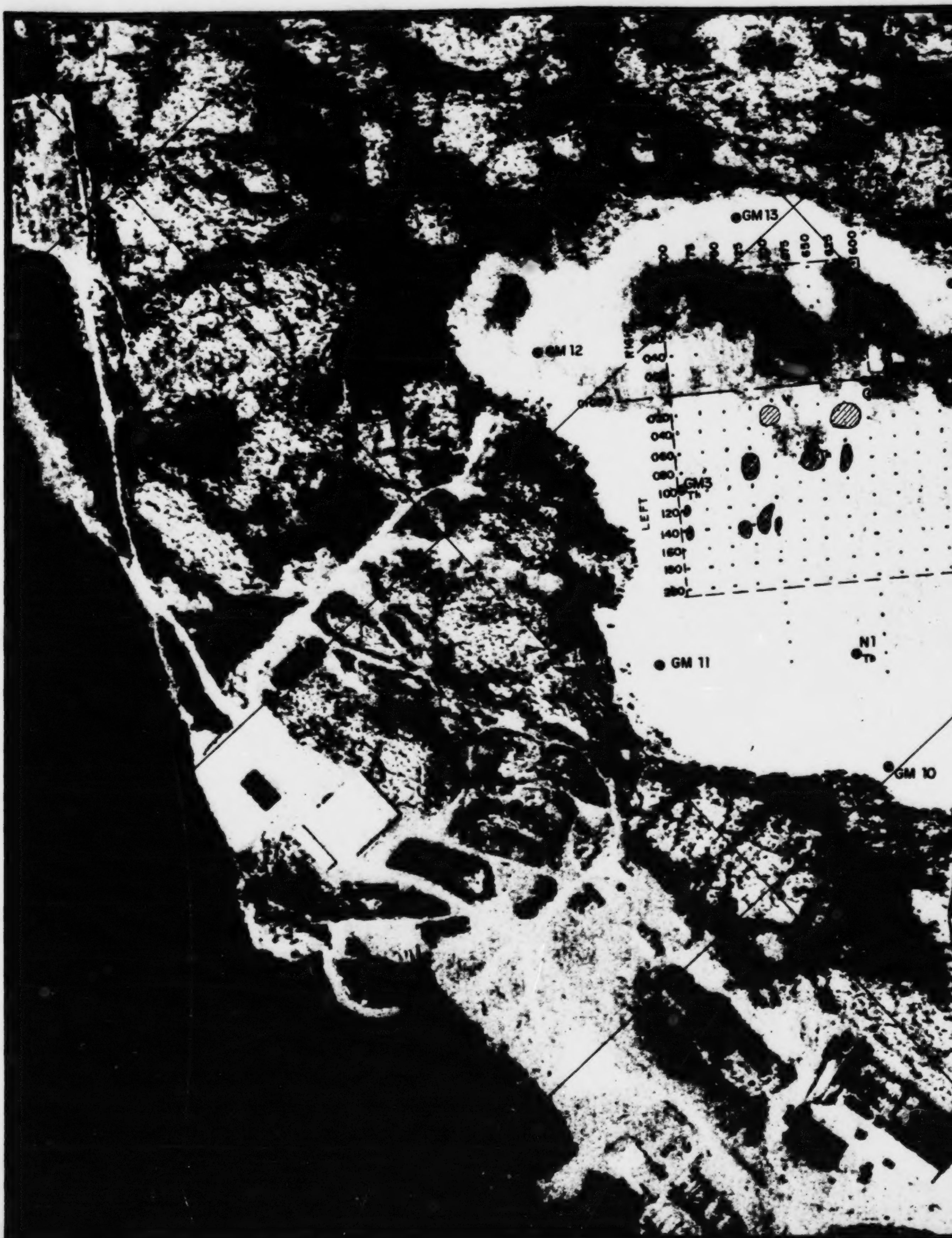
The EM survey was laid out to cover a substantial representative portion of the Gunnar Main Tailings containing suspected areas of discontinuous permafrost. Snow depth measurements were taken at the same locations as the EM survey readings. Figure No. 10.2 illustrates the area surveyed and the locations of individual readings. Photograph No. 10.3 shows the baseline for the survey and Photograph No. 10.4 shows readings being taken.

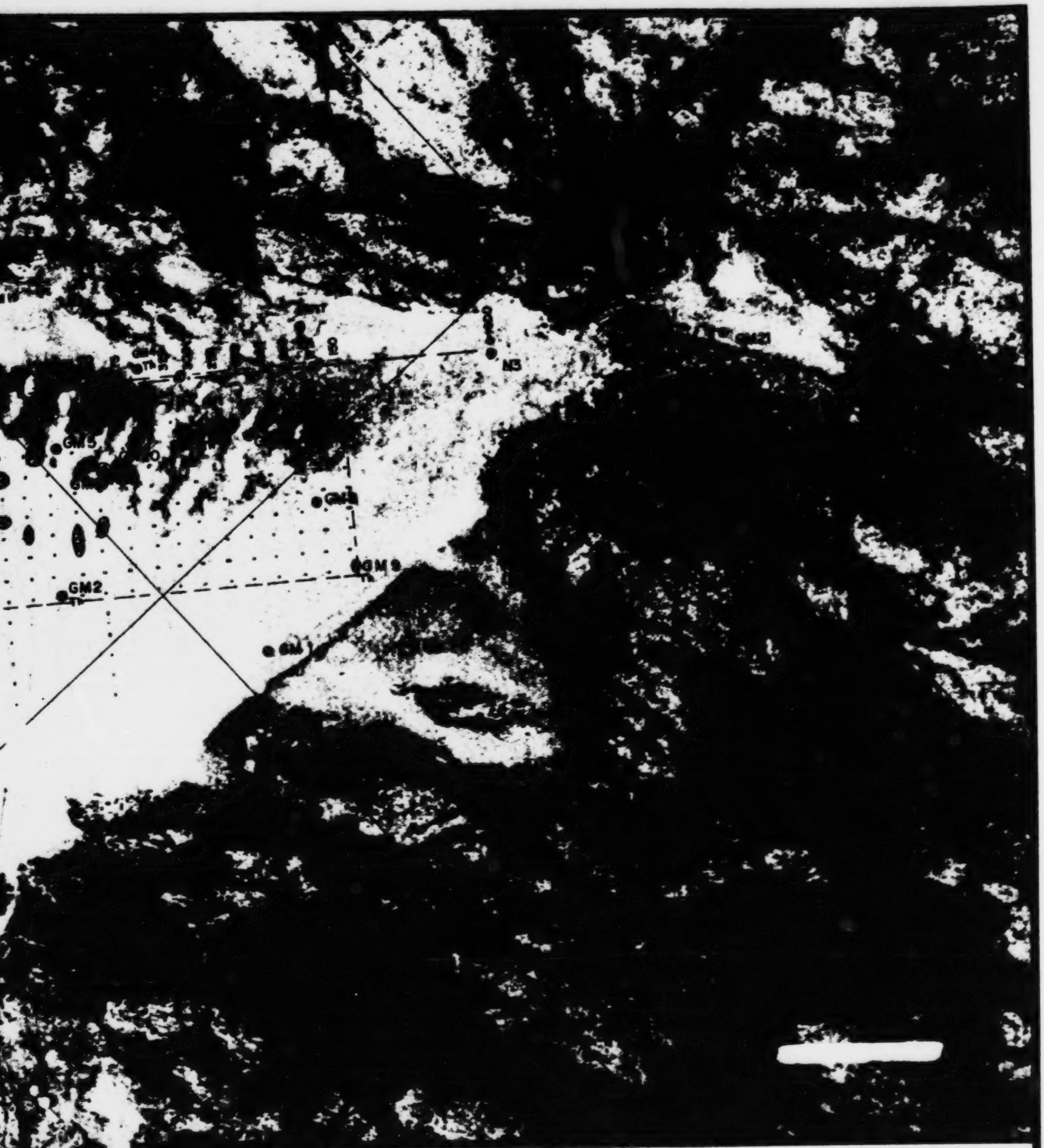
The observation of drill cuttings was made in the holes drilled for thermistor installations in addition to holes which had already been drilled or were going to be drilled for other purposes.

10.1.3 Observation Frequency

The planned observation frequency for the thermistors was to be approximately bimonthly and coincidental with other sampling campaigns on site. The observation period extended from the time of installation (March 1985) until the end of the field campaigns (August 1985), to provide measurements during winter to late summer conditions.

The EM survey was to be conducted on 2 occasions; one observation during the March campaign under winter conditions, and a subsequent observation during late summer conditions. However, based on the results obtained from the first EM survey, as discussed in Section 10.5, it was concluded that there would be minimal benefit derived from the summer EM survey and it was subsequently cancelled.


GM 13
650
600
GM 12
RIGHT
040
020
040
060
080
100
GM3
Th
120
140
160
180
200
LEFT
N1
Th
GM 11
GM 10



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P. E. Pehme MSc.

EM SURVEY LOCATIONS

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1: 5000
DATE DEC. '85
DRAWN BY W.T.
APPROVED BY

FIGURE 10.2

PHOTOGRAPH NO. 10.3

Gunnar Main showing the EM survey base line of the grid. Note the wind erosion of the exposed tailings (March 1985).

PHOTOGRAPH NO. 10.4

Conducting the Gunnar Main EM Survey
(March 1985).

Snow depth measurements were made during the March campaign only.

10.2 FIELD PROCEDURES

10.2.1 Equipment Description

The thermistor installations were provided as pre-assembled units with thermistor and wire leads prepared with either 8 or 10 thermistors per string. Thermistors were selected which would provide a reasonably high degree of resolution in near-freezing temperatures, and be suitable for use in below freezing conditions. It was necessary to order the thermistor strings in advance of fieldwork and therefore, the lengths had to be anticipated. The strings were provided in two configurations with 5 m leads provided for installation and reading. One configuration contained 6 thermistors spaced at 0.5 m intervals (from the bottom up), and then 2 at 1.0 m spacing (8 total with a total length of 9.5 m). The other included 8 lower thermistors spaced at 0.25 m intervals and 2 upper thermistors at 1.0 m intervals (10 total with a total length of 8.75 m). Thermistors had been requested with color-coded leads to identify depths, but unfortunately, the supplied leads were all identical and marker tabs had been attached for identification. There is concern that the marker numbers will fade with time.

Thermistor readings were taken with a Fluke Model 77 digital analog multimeter. The instrument has internal current limitation to avoid generating induced heat in the thermistor resistance.

The electromagnetiv (EM) survey was conducted with both EM31 and EM34 instruments manufactured by Geonics Ltd. A description of the equipment operation is provided in Section 10.5.

10.2.2 Installation Methods

The thermistor strings were installed in holes drilled with the vibration-rotation drill used for the other drilling and installation work on the site (refer to Volume 4, Appendix 3). The drill holes were BQ (nominal 60 mm) size. Table 10.1 provides the location, elevation and installation information for the thermistor strings. Table 10.3 (Section 10.4.2) details the depth to the individual thermistor points together with various observations. Three methods of installation of the thermistor strings were used once the test hole had been drilled, sampled and the casing withdrawn:

1) The thermistor string was taped to the outside of the piezometer pipe and the piezometer was installed. The test hole was allowed to collapse and also was backfilled with tailings, or,

2) The thermistor string was weighed on the end and lowered down in the test hole as far as desired or practical (to the top of the sloughed soil). The test hole was then backfilled with tailings, or

3) The thermistor string was lowered down a piezometer that had been previously installed and was attached at the top.

Equipment difficulties as well as soil sloughing conditions dictated the method of installation. The equipment limitations precluded installation to the full depth desired (see Table 10.1) and the drill breakdown time prevented completion of all the installations as planned. Method 2 was used where soil sloughing was not extensive, while method 1 was used below the water table to attempt to achieve the desired depth. Method 3 was used as a last resort when the time that had been allotted to the March campaign had expired.

It was intended that, where frozen tailings were believed present, the thermistor points would be positioned to provide accurate delineation of the active layer boundary. However, given the difficulties of winter conditions, limitations related to drilling equipment and the absence of a thawed layer at most locations, it is apparent that ideal installations were not achieved in all cases.

TABLE 10.1

TEST HOLE AND THERMISTOR INFORMATION

Location Information	Northing (m)	Easting (m)	Ground Elevation (m)	Thermistor String Length (m)	Test Depth Drilled (m)	Depth Below Ground Surface Lowest Thermistor (m)	Comments
N1C	1232	3883	106.64	9.5	11.89	8.92	Installed inside the monitor well.
N1F	1227	3875	106.64	9.5	4.9	4.00	String taped to outside of monitor well.
N2F	1342	3701	101.81	8.75	12.2	3.44	String taped to outside of monitor well.
N6A	1634	3905	99.99	9.5	11.25	8.8	Installed inside the monitor well.
GM2A	1425	3928	104.10	8.75	8.4	5.27	Installed in test hole and backfilled with tailings.
GM3A	1214	3631	101.98	9.5	19.8	4.4	Installed in test hole and backfilled with tailings.
GM4A	1632	3315	100.92	9.5	4.8	4.2	Installed in test hole and backfilled with tailings.
GM6A	1543	3863	101.68	8.75	11.0	4.15	String taped to outside of monitor well.
GM9B	1658	4107	101.44	8.75	4.10	4.83	String taped to outside of monitor well.

The EM survey did not involve any installation work except for survey control markers. Section 10.5 discusses the EM survey in detail. (Also see Photograph No. 10.4.)

The depth of snow was measured by probing with a stake.

10.2.3 Field Observations

Thermistor readings were generally obtained on 6 occasions between late March and late August 1985. Results of the observations are shown on Table 10.3 (Section 10.4.2). The string which had been installed in Monitor Well N1C was removed in June to facilitate use of the monitor well. Three of the installations (N1C, N6A and GM9B) were installed at the end of the March campaign and observations did not commence until May 1985. The observations were converted to degrees using the temperature calibration data provided by YSI (see Figure No. 10.3). For observations between the values given in the calibration table, a linear interpolation was made. A short program in IBM Basic was written to facilitate the calibrations and a listing is provided below:

```
10      REM THIS PROGRAM CALCULATES THE TEMPERATURE FOR THE YSI
        THERMISTOR PROBE
20      DIM REST(60)
60      FOR TEMP%=1 TO 51
70      READ REST(TEMP%)
80      NEXT TEMP%
82      DATA 48560,45830,43270,40860,38610,36490,34500,32630,30880,
        29230,27670,26210,24830,23540,22320,21170,20080,19060,18100,
        17190,16330,15520,14750,14030,13340,12700,12090,11510,10960,
        10440,9951,9486,9046,8628,8232,7857
84      DATA 7500,7162,6841,6536,6247,5972,5710,5462,5225,5000,4787,
        4583,4389,4204,4029
90      LINE INPUT "RESISTANCE   "; REPLY$
95      REPLY=VAL(REPLY$)
100     FOR TEMP%=2 TO 51
110     IF REPLY=REST(TEMP%) THEN DEGREE=(TEMP%-21) :GOTO 130
120     IF REST(TEMP%-1)>REPLY AND REPLY>REST(TEMP%) THEN
        DEGREE=TEMP%-22+((REST(TEMP%-1)-REPLY)/
        (REST(TEMP%-1)-REST(TEMP%)))
130     NEXT TEMP%
135     DEGREE=INT(DEGREE*10+.5)/10
140     PRINT "TEMPERATURE   ";DEGREE
150     GOTO 90
```

YSI PRECISION THERMISTOR

1215

YSI 44007

RESISTANCE 5000 OHMS @25°C

Interchangeability: ±0.2°C (See Tolerance Curves).

Max. Operating Temp: 150°C (300°F).

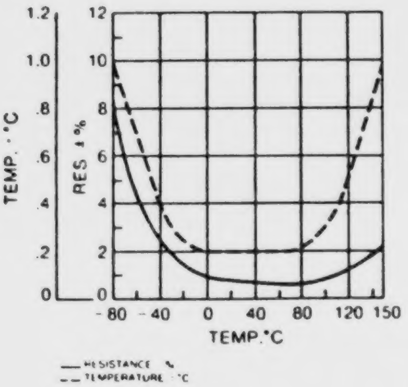
Time Constant, Max: 1 sec. in well stirred oil, 10 sec. in still air. Time constant is the time required for a thermistor to indicate 63% of a newly impressed temperature.

Dissipation Constant, Min: 8mW/°C in well stirred oil, 1mW/°C in still air. Dissipation constant is the power in milliwatts to raise a thermistor 1°C above surrounding temperature.

Color Code: Black epoxy body, violet end.

Storage Temperature: -80° to +120°C (-112° to +250°F).

Tolerance Curves: The following curves indicate conformance to standard resistance temperature values as a % of resistance, and as a maximum interchangeability error expressed as temperature.



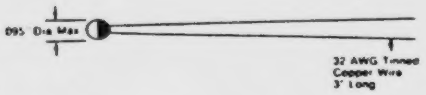
WARNING

Use heat sinks when soldering or welding to thermistor leads.

Industrial Division
Yellow Springs Instrument Co.
Yellow Springs, Ohio 45387, U.S.A.
Phone 513-767-7241

ITEM 003242 P/N B44507-E Printed in U.S.A. MP

YSI PRECISION THERMISTOR



RESISTANCE VERSUS TEMPERATURE —80° to +150°C

TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES	TEMP°C	RES
−80	3684K	−50	335.3K	−20	48.56K	+ 10	9951	+ 40	2663	+ 70	875.7	+100	339.6	+130	150.3
79	3371K	49	312.3K	19	45.83K	11	9486	41	2559	71	846.4	101	329.8	131	146.5
78	3086K	48	291.0K	18	43.27K	12	9046	42	2459	72	818.3	102	320.4	132	142.9
77	2827K	47	271.3K	17	40.86K	13	8628	43	2363	73	791.2	103	311.3	133	139.4
76	2592K	46	253.0K	16	38.61K	14	8232	44	2272	74	765.1	104	302.5	134	136.0
75	2378K	45	236.2K	15	36.49K	15	7857	45	2184	75	740.0	105	294.0	135	132.6
74	2182K	44	220.5K	14	34.50K	16	7500	46	2101	76	715.9	106	285.7	136	129.4
73	2005K	43	205.9K	13	32.63K	17	7162	47	2021	77	692.7	107	277.8	137	126.3
72	1843K	42	192.5K	12	30.88K	18	6841	48	1944	78	670.3	108	270.1	138	123.2
71	1695K	41	180.0K	11	29.23K	19	6536	49	1871	79	648.8	109	262.6	139	120.3
−70	1560K	−40	168.3K	−10	27.67K	+ 20	6247	+ 50	1801	+ 80	628.1	+110	255.4	+140	117.4
69	1436K	39	157.5K	9	26.21K	21	5972	51	1734	81	608.2	111	248.4	141	114.6
68	1323K	38	147.5K	8	24.83K	22	5710	52	1670	82	588.9	112	241.6	142	111.9
67	1220K	37	138.2K	7	23.54K	23	5462	53	1608	83	570.4	113	235.1	143	109.2
66	1126K	36	129.5K	6	22.32K	24	5225	54	1549	84	552.6	114	228.7	144	106.7
65	1039K	35	121.4K	5	21.17K	25	5000	55	1493	85	535.4	115	222.6	145	104.2
64	959.9K	34	113.9K	4	20.08K	26	4787	56	1439	86	518.8	116	216.7	146	101.8
63	887.2K	33	106.9K	3	19.06K	27	4583	57	1387	87	502.8	117	210.9	147	99.40
62	820.5K	32	100.3K	2	18.10K	28	4389	58	1337	88	487.4	118	205.3	148	97.10
61	759.2K	31	94.22K	− 1	17.19K	29	4204	59	1290	89	472.6	119	199.9	149	94.87
−60	702.9K	−30	88.53K	0	16.33K	+ 30	4029	+60	1244	+90	458.2	+120	194.7	+150	92.70
59	651.1K	29	83.22K	+ 1	15.52K	31	3861	61	1200	91	444.4	121	189.6		
58	603.5K	28	78.26K	2	14.75K	32	3702	62	1158	92	431.0	122	184.7		
57	559.7K	27	73.62K	3	14.03K	33	3549	63	1117	93	418.2	123	179.9		
56	519.4K	26	69.29K	4	13.34K	34	3404	64	1079	94	405.7	124	175.3		
55	482.2K	25	65.24K	5	12.70K	35	3266	65	1041	95	393.7	125	170.8		
54	447.9K	24	61.45K	6	12.09K	36	3134	66	1006	96	382.1	126	166.4		
53	416.3K	23	57.90K	7	11.51K	37	3008	67	971.1	97	370.9	127	162.2		
52	387.1K	22	54.58K	8	10.96K	38	2888	68	938.0	98	360.1	128	158.1		
51	360.2K	21	51.47K	9	10.44K	39	2773	69	906.3	99	349.7	129	154.1		

FIGURE NO. 10.3 YSI Thermistor Calibration Data

Snow cover depths were measured in conjunction with the EM survey in March. Observations from the EM survey are provided in Section 10.5.

10.3 QUALITY ASSURANCE/QUALITY CONTROL

10.3.1 Field Procedures

The QA/QC for field drilling procedures and EM survey procedures are summarized in Volume 4, Appendix 3 and Section 10.3 of this appendix, respectively. Snow depth measurements are considered accurate within ±0.01 m.

10.3.2 Precision, Accuracy and Detection Limits

The achievable accuracy of the thermistor readings was 0.1°C. Some operator error was introduced where the leads were held on the Fluke multimeter with wet fingers. This effect was noticed during the August campaign and it is difficult to estimate which readings maybe in error. It may be reasonable to assume that the majority of the readings taken up to June 1985 were done in cold weather and that the operator used gloves. The readings from the August campaign were done without touching the leads by hand. However, the June 20, 1985 and possibly the May 20, 1985 readings may have been affected. Table 10.2 provides an indication of the magnitude of the possible error.

TABLE 10.2

THERMISTOR READING ERRORS

	Reading (ohms)	**Temperature (°C)**	**Reading (ohms)**	**Temperature (°C)**
No Finger Contact	6 090	20.6	29 090	-10.9
	6 100	20.5	28 960	-10.8
Fingers Held Lightly	6 080	20.6	29 100	-10.9
	6 040	20.8	28 890	-10.8
Fingers Held Tightly	6 010	20.9	29 190	-11.0
	5 960	21.0	28 840	-10.7
Fingers Wet	5 560	22.6	26 780	- 9.4
	5 620	22.4	26 560	- 9.2
Air Temperature		23.0		-11.6

Since some of the thermistor strings were installed within monitor wells, thermal conductance would tend to mask the ground temperature to some extent at above freezing temperatures. The readings should be interpreted in accordance with the installation method and the possibility of reading errors.

10.4 DATA PRESENTATION

10.4.1 Test Hole Summaries

Included in this section are 13 test hole summaries from within the EM survey area which represent the 9 holes in which thermistors were installed, holes in which ground temperature measurements were obtained during drilling, and 1 additional hole in which ground ice was noted. Substantial additional information with respect to geotechnical tailings properties, additional test hole data, water table data and hydraulic conductivities is presented in other volumes of this study. In the interest of brevity, this information has not been reproduced in this volume. In Section 10.6 summaries of this data will be discussed where it is considered relevant to the analysis and conclusions. For a detailed presentation please refer to:

Volume 4 - Tailings Solids and Surrounding Soils

Volume 5 - Groundwater

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: N1C

DRILLER / EXCAVATOR: McNeill

SITE COORDINATES:

N 1232

E 3883

COMPLETION DATE: 84/12/09

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m) 11.89

GROUND ELEVATION (m) 106.50

WELL OWNER NUTP

INSTALLER G. Bell

INSTALLATION DATE 84/12/09

CASING ELEV. (m) 106.88

CASING LENGTH (m) 10.05

CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)

FORMATION OF COMPLETION: Tailings

SEAL (END) DEPTH (m)

OPEN / SCREEN DEPTH (m) 9.67

OPEN / SCREEN LENGTH (m) 0.127

OPEN / SCREEN AREA (m^2) 0.0203

LITHOLOGICAL SUMMARY

0.38 m

DEPTH ft		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S1B		SM	8.2	1410			SAND, moist, med. dense, poorly graded, (uniform), med. reddish brown, some silt.
		1						
5	S2B	2	SM	7.1	1037			As above.
10		3						
	S3B		SM	8.4	1350		non-plastic	As above, non-plastic, silty.
		4						
15	S4B	5	SM	12.8				SAND, silty, moist, med. dense fine, poorly graded, med. reddish brown, lost sample (vibrated out of test hole).
		6						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: N1C

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft. m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
S5B	SM	13.2	1669		non-plastic	As above.
25 S6B	SM	17.2	1574			As above, silty.
30 S7B	SM	15.4 16.1	1664			As above, wet, silty.
35 S8B	SM	14.8	1652			Wet, silty.
S9B	SM	14.9 21.6	1380			Good recovery, very silty.
40 45						N1C was about 3 m SE of N1B. A 9.5 m thermistor was installed with the lowest thermistor at 9.3 m below top of pipe. The thermistor was installed inside the existing piezometer pipe.

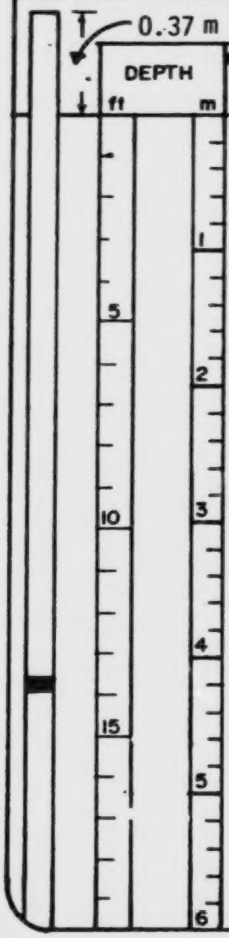
TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: N1F - 0.5 m W of N1E
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
COMPLETION DATE: 85/03/27
N 1227
TEST HOLE DIAMETER (m): 0.056
E 3890
TOTAL DEPTH (m) 4.90
GROUND ELEVATION (m) 106.64

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/27 10:15
SEAL (END) DEPTH (m)
CASING ELEV. (m) 107.01*
OPEN/SCREEN DEPTH (m) 4.15
CASING LENGTH (m) 4.52
OPEN/SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN/SCREEN AREA (m^2) 0.0203

LITHOLOGICAL SUMMARY



UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					Hard drilling, could not get below 4.9 m. Could not clean out hole due to dry sand. Pipe installed so 6.0 m thermistor ~ 0.5 m below grade. 9.5 m string thermistor installed. Lowest at 4.0 m. Thermistor string taped to outside of piezometer pipe. Piezometer only installed and no samples were recovered.

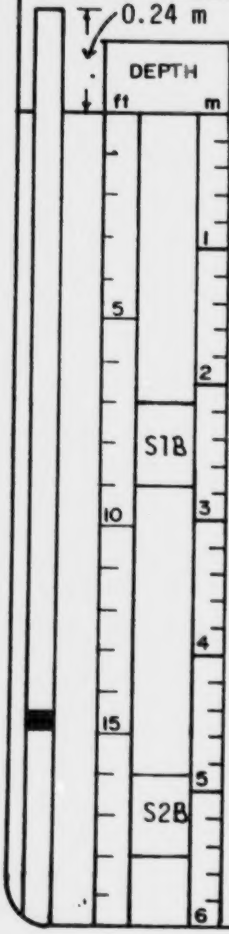
* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID:	Gunnar Main	TH - TEST HOLE / TP - TEST PIT:	TH
LOCATION ID:	N2A	DRILLER / EXCAVATOR:	McNeill
SITE COORDINATES:		COMPLETION DATE:	84/12/02
N	1336	TEST HOLE DIAMETER (m):	0.056
E	3702	TOTAL DEPTH (m)	5.49
GROUND ELEVATION (m)	101.83		
WELL OWNER	NUTP	FILTER PACK LENGTH (m)	
INSTALLER	G. Bell	FORMATION OF COMPLETION:	Tailings
INSTALLATION DATE	84/12/02	SEAL (END) DEPTH (m)	
CASING ELEV. (m)	102.07	OPEN/SCREEN DEPTH (m)	4.42
CASING LENGTH (m)	4.66	OPEN / SCREEN LENGTH (m)	0.127
CASING DIAMETER (m)	0.035	OPEN / SCREEN AREA (m²)	0.0203

LITHOLOGICAL SUMMARY



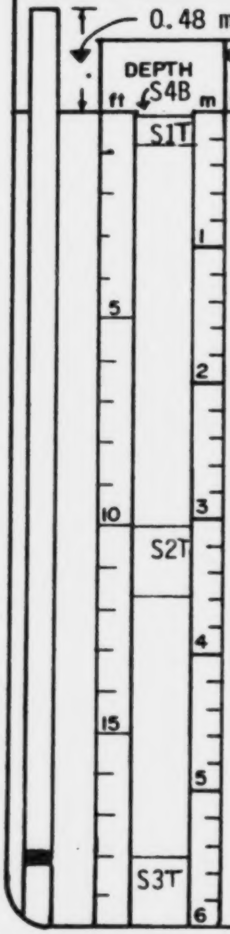
UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					Frost at 0.6 to 0.9 m. Water at 1.5 m.
ML	65.4				SILT, very sandy, med. reddish brown, frozen lenses of water, ice from 3.66 to 4.88 m.
SM	20.8				SAND, some silt, moist to wet, med. dense, fine, poorly graded med. to dark brown, trace of clay.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main	TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: N2F	DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:	COMPLETION DATE: 85/03/22
N 1342	TEST HOLE DIAMETER (m): 0.056
E 3701	TOTAL DEPTH (m) 12.2
GROUND ELEVATION (m) 101.81	
WELL OWNER NUTP	FILTER PACK LENGTH (m)
INSTALLER R. Boivin	FORMATION OF COMPLETION: Tailings
INSTALLATION DATE 85/03/22 16:07	SEAL (END) DEPTH (m)
CASING ELEV. (m) 102.29 *	OPEN/SCREEN DEPTH (m) 5.57
CASING LENGTH (m) 6.05	OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035	OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY



DEPTH	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	Pw (%)	Lw (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1T	SM					Biological Samples: SAND - frozen, poorly graded, fine, reddish brown, silty. Sample S4 taken from ground surface as S1 sample may be contaminated.
S2T	SM					Tube S2 pushed from 1.2 m to 1.8 m, no recovery. Pushed to 3.6 m, recovery. Sample would not stay in tube, put into bag.
S3T	SM					

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: N2F

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft.	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
25 30 35 40 45	7 8 9 10 11 12 13 14 15						8.75 m - Thermistor string installed, lowest at 3.44 m below grade. Piezometer could not be vibrated past 5.57 m. Nothing in sampler at 9.2 m, 10.6 m and 12.2 m. Thermistor string taped on outside of piezometer pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TH
LOCATION ID: N6A
DRILLER / EXCAVATOR: Wiseman
SITE COORDINATES:
N 1634
E 3905
COMPLETION DATE: 85/03/09
TEST HOLE DIAMETER (m): 0.056
TOTAL DEPTH (m) 11.25
GROUND ELEVATION (m) 99.87

WELL OWNER NUTP
FILTER PACK LENGTH (m)
INSTALLER R. Boivin
FORMATION OF COMPLETION: Clay
INSTALLATION DATE 85/03/09 11:45
SEAL (END) DEPTH (m)
CASING ELEV. (m) 100.37
OPEN/SCREEN DEPTH (m) 11.0
CASING LENGTH (m) 11.50
OPEN / SCREEN LENGTH (m) 0.127
CASING DIAMETER (m) 0.035
OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY

0.50 m

DEPTH ft	DEPTH	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S8B		SM	23.0				
	S1B	1	SM	21.5				SAND - very poorly graded, fine, reddish brown, silty, frozen.
5	S2T	2	SM	40.4				End of frost at 2.0 m. No recovery at 2.3 m. Saturated.
10		3						No recovery at 3.0 m.
		4						SILT - very sandy, moist, stiff, non-plastic, reddish brown. Very little recovery at 4.6 m
15	S3B		ML	21.1				Lake Bottom at 5.3 m. CLAY - damp, very stiff, medium plastic, dark green, roots, coal specks. trace of sand. pp 150 to 240 kPa
		5	Tailings Interface					
	S4B	6	CI	35.9				

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: N6A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft. m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
S5T	ML	20.7	1594	22.2	24.1	SILT, sandy reddish brown, in Shelby tube, probably slough (6.1 m).
	CI-CH					CLAY, moist, stiff, medium to highly plastic, grey, pp 100 kPa at 5.49 m
S6B	CI	43.1				
S7T	CI	36.0	1387	21.9	41.0	Auger refusal at 11.25 m. End of hole, pipe installed, possibly bedrock. 9.5 m - Thermistor installed with lowest thermistor at 7.5m below top of pipe. Thermistor string installed inside piezometer pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: GM2A

DRILLER / EXCAVATOR: Wiseman

SITE COORDINATES:

N 1426

E 3928

COMPLETION DATE: 85/03/29

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m) 8.40

GROUND ELEVATION (m) 104.10

Thermistor OWNER NUTP (8.75)

FILTER PACK LENGTH (m)

INSTALLER R. Boivin

FORMATION OF COMPLETION:

INSTALLATION DATE 85/03/29

SEAL (END) DEPTH (m)

CASING ELEV. (m)

8.75m THERM DEPTH (m) 5.27

CASING LENGTH (m)

OPEN / SCREEN LENGTH (m)

CASING DIAMETER (m)

OPEN / SCREEN AREA (m^2)

LITHOLOGICAL SUMMARY

DEPTH ft		m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S1B		SP	8.1				SAND - frozen to 1.1 m, damp below frost, medium dense, poorly graded, fine, reddish brown, frozen silt layers Vs and Nbn.
		1						
5	S2B		SP and ML layers	11.4				
		2						
10	S3B	3	SP and ML layers	14.7				Permafrost - layers from 1.1 to 3.0 m and depending on tube - to between 3.0 m and 3.8 m; solid ice and soil from approx. 3.8 m to 5.1 m - End at 5.1 m
	S4T		SP	26.5	1519			
		4						
15	S5B		Nbe and V	24.7				Ice lenses
		5						
	S6B		SM	23.6	1673			SAND - damp to moist, medium dense, poorly graded, fine, reddish brown, silty.
		6						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM2A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft. m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
S7T	SM	18.1	1668			SAND - as above Nothing in sampler at 7.6 m, free water. Tailings Interface
S8B	CL	11.1				CLAY (gravelly) - damp, very stiff to hard, low plastic, dark greenish grey, very gravelly. Auger refusal at 8.4 m. 8.75 m string thermistor installed lowest at 5.27 m. Thermistor string installed in test hole and back filled with tailings.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TP

LOCATION ID: GM2D

DRILLER / EXCAVATOR: G. Feasby

SITE COORDINATES:

COMPLETION DATE: 85/08

N 1425

TEST HOLE DIAMETER (m):

E 3928

TOTAL DEPTH (m) 1.3

GROUND ELEVATION (m) 104.10

WELL OWNER

FILTER PACK LENGTH (m)

INSTALLER

FORMATION OF COMPLETION:

INSTALLATION DATE

SEAL (END) DEPTH (m)

CASING ELEV. (m)

OPEN/SCREEN DEPTH (m)

CASING LENGTH (m)

OPEN / SCREEN LENGTH (m)

CASING DIAMETER (m)

OPEN / SCREEN AREA (m^2)

LITHOLOGICAL SUMMARY

DEPTH ft / m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
		4.9	1361			14°C
		4.7	1343			12.2°C
		14.3	1278			10.5°C
		7.0	1324			8.5°C

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 3

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: GM3A

DRILLER / EXCAVATOR: Wiseman & McNeill

SITE COORDINATES:

N 1214

E 3631

COMPLETION DATE: 85/03/28

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m) 19.8

GROUND ELEVATION (m) 101.98

OWNER NUTP (Thermistor)

INSTALLER R. Boivin

INSTALLATION DATE 85/03/28

CASING ELEV. (m)

CASING LENGTH (m)

CASING DIAMETER (m)

FILTER PACK LENGTH (m)

FORMATION OF COMPLETION:

SEAL (END) DEPTH (m)

OPEN / SCREEN DEPTH (m)

OPEN / SCREEN LENGTH (m)

OPEN / SCREEN AREA (m^2)

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
~~S1B~~	SP	7.9				SAND - frozen to 0.7 m, damp below frost, medium dense, poorly graded, fine, reddish brown.
S2B	SM	19.7				
S3B	ML	22.7	1695			Damp to moist.
S4T	SP	24.1	1556			
S5B	SM	22.3				
S6B	SM	18.6				

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 3

SITE ID: Gunnar Main

LOCATION ID: GM3A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft.		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
	S7T		SM	19.5	1697			Minimal recovery
		7						
25								Nothing in sampler at 7.6 m
		8						
30	S8B	9	ML	24.6	1634			SILT - very sandy
	S9T		SM	28.2	1509			SAND - as above
		10						
	S10 B		SM and		Tailings			SAND
35			OL	42.8	Interface			ORGANIC CLAY - damp, stiff, medium plastic, green, odour.
		11						
	B1B	12	Slough	21.6				Intended as biological sample, but another sample was used.
40	S11B		OL	79.8				ORGANIC CLAY - as above
	S12B		SM slough and OL and		CI bottom			CLAY - damp, stiff to very stiff, medium plastic, grey.
		13						
								Drilled to 19.8 m, no bedrock.
45								
		14						
		15						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 3 OF 3

SITE ID: Gunnar Main

LOCATION ID: GM3A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft.		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
50								
		16						
55								
		17						
		18						
60								
		19						
65	S13 B		CI	34.2				Thermistor string installed an backfilled with tailings. The string was 9.5 m long with the 9.5 m long thermistor at a depth of 4.4 m below ground surface.
		20						
		21						
70								
		22						
75		23						
		24						

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: GM4A

DRILLER / EXCAVATOR: Wiseman

SITE COORDINATES:

COMPLETION DATE: 85/03/12

N 1632

TEST HOLE DIAMETER (m): 0.056

E 3815

TOTAL DEPTH (m) 4.8 m *

GROUND ELEVATION (m) 100.92

Thermistor OWNER NUTP

FILTER PACK LENGTH (m)

INSTALLER R. Boivin

FORMATION OF COMPLETION:

INSTALLATION DATE 85/03/12

SEAL (END) DEPTH (m)

CASING ELEV. (m)

OPEN/SCREEN DEPTH (m)

CASING LENGTH (m)

OPEN / SCREEN LENGTH (m)

CASING DIAMETER (m)

OPEN / SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH ft		DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
	S1B		ML	36.5				SILT - frozen to 1.0 m, firm, low plastic, reddish brown, trace of sand, trace of clay,
5	S2T	1	SM	14.7	1245			Probably slough. 9.5 m thermistor string installed with 9.5 m thermistor at 4.2 m below ground surface. Backfilled with tailings.
10	S3B	3	SM	20.9				SAND - very moist, poorly graded, fine, dark reddish brown, silty.
15	S4B		SM	24.9	Tailings			Saturated.
	S5B	5	CI	25.2	Interface			CLAY - moist, medium plastic, very stiff, grey-brown. Auger refusal at 4.8 m. 9.5 m String thermistor installed, lowest at 4.20 m. * (taped to outside of casing)

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 2

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: GM6A On Knoll

DRILLER / EXCAVATOR: Wiseman

SITE COORDINATES:

COMPLETION DATE: 85/03/14

N 1543

TEST HOLE DIAMETER (m): 0.056

E 3863

TOTAL DEPTH (m) 11.0

GROUND ELEVATION (m) 101.68

Thermistor OWNER NUTP

FILTER PACK LENGTH (m)

INSTALLER R. Boivin

FORMATION OF COMPLETION:

INSTALLATION DATE 85/03/14

Lowest Therm. DEPTH (m) 4.15

CASING ELEV. (m) 101.98 *

OPEN/SCREEN DEPTH (m) 4.15

CASING LENGTH (m) 4.45

OPEN / SCREEN LENGTH (m) 0.127

CASING DIAMETER (m) 0.035

OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
S1B	SM Vx	15.2				SAND - some frozen, some dry, visible ice crystals in frozen portion, poorly graded, fine, reddish brown and grey brown, reddish brown portions appear to be frozen, grey brown silty.
S2B	SM					Attempted tube at 1.8 m, no recovery.
S3B	SM	22.6				SAND - silty, frozen, very moist below frost, visible ice excess, crystals.
S8B	ICE & soil inclusions					3.6 m - ICE with soil inclusions.
S4B	ML	32.6				Less ice at 4.2 m again. SILT - saturated, low to non-plastic, reddish brown, sandy. Frost ends at 4.3 m. Nothing in core barrel at 4.6 m, nothing in core barrel at 6.0 m.

Depth scale: ft 5, 10, 15; m 1, 2, 3, 4, 5, 6.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 2 OF 2

SITE ID: Gunnar Main

LOCATION ID: GM6A

LITHOLOGICAL SUMMARY (CONTINUED)

DEPTH ft.	DEPTH m		UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m^3)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION : SOIL TYPE AND COLOR
	7							
25	8	S5B	ML	33.5				SILT - saturated, low to non-plastic, reddish brown, sandy, greenish brown layers, trace roots, silty.
30	9							Nothing in core barrel at 9.1 m.
	10							
35		S6B	CI					Minimal recovery at 10.7 m. CLAY - saturated, medium plastic, soft, light grey.
	11							Casing refusal at 11.0 m.
40	12							8.75 m string thermistor installed, lowest at 4.15 m. Could not get pipe any lower even after cleaning out hole twice.
	13							Thermistor installed on outside of pipe.
45	14							
	15							

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TP

LOCATION ID: GM6C

DRILLER / EXCAVATOR: G. Feasby

SITE COORDINATES:

N 1543

E 3863

COMPLETION DATE: 85/08

TEST HOLE DIAMETER (m):

TOTAL DEPTH (m) 1.37

GROUND ELEVATION (m) 101.68

WELL OWNER

FILTER PACK LENGTH (m)

INSTALLER

FORMATION OF COMPLETION:

INSTALLATION DATE

SEAL (END) DEPTH (m)

CASING ELEV. (m)

OPEN/SCREEN DEPTH (m)

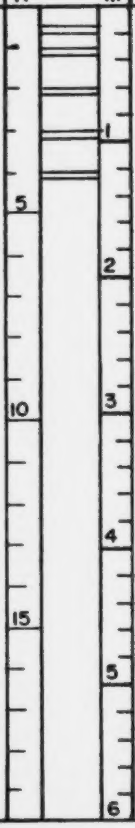
CASING LENGTH (m)

OPEN / SCREEN LENGTH (m)

CASING DIAMETER (m)

OPEN / SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH ft m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
		10.8	1197			11.2°C
		26.3	1085			
		16.3	1213			
		28.3	1235			7.8°C at 0.76 m
		28.0	1400			3.5°C at 1.07 m
						1.0°C at 1.22 m
						0.0°C at 1.37 m

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main

TH - TEST HOLE / TP - TEST PIT: TH

LOCATION ID: GM9B

DRILLER / EXCAVATOR: Wiseman

SITE COORDINATES:

N 1658

E 4107

COMPLETION DATE: 85/03/10

TEST HOLE DIAMETER (m): 0.056

TOTAL DEPTH (m) 4.1

GROUND ELEVATION (m) 101.44

WELL OWNER NUTP

INSTALLER R. Boivin

INSTALLATION DATE 85/03/10 10:59

CASING ELEV. (m) 101.81 *

CASING LENGTH (m) 4.47

CASING DIAMETER (m) 0.035

FILTER PACK LENGTH (m)

FORMATION OF COMPLETION: Tailings

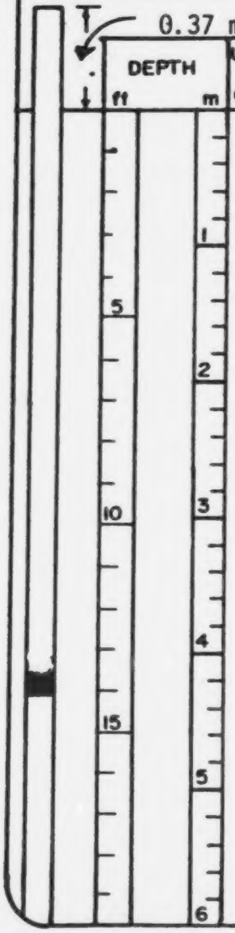
SEAL (END) DEPTH (m)

OPEN/SCREEN DEPTH (m) 4.10

OPEN / SCREEN LENGTH (m) 0.127

OPEN / SCREEN AREA (m²) 0.0203

LITHOLOGICAL SUMMARY



UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
					8.75 m Thermistor string installed with lowest thermistor at 5.2 m below top of pipe. ** Thermistor string installed outside the piezometer pipe. No samples retrieved. ** Fieldnote concerning lowest thermistor depth does not coincide with lowest depth of piezometer. Therefore assumed lowest thermistor at 4.2 m below top of pipe.

* Elevation calculated from ground elevation plus pipe.

TEST HOLE, TEST PIT, or WELL SUMMARY

PAGE 1 OF 1

SITE ID: Gunnar Main
TH - TEST HOLE / TP - TEST PIT: TP
LOCATION ID: GM20
DRILLER / EXCAVATOR: G. Feasby
SITE COORDINATES: (New Hole)
COMPLETION DATE: 85/08
N 1550
TEST HOLE DIAMETER (m):
E 3870
TOTAL DEPTH (m) 1.43
GROUND ELEVATION (m) 100.0 ±

WELL OWNER
FILTER PACK LENGTH (m)
INSTALLER
FORMATION OF COMPLETION:
INSTALLATION DATE
SEAL (END) DEPTH (m)
CASING ELEV. (m)
OPEN/SCREEN DEPTH (m)
CASING LENGTH (m)
OPEN / SCREEN LENGTH (m)
CASING DIAMETER (m)
OPEN / SCREEN AREA (m²)

LITHOLOGICAL SUMMARY

DEPTH ft	DEPTH m	UNIFIED SOIL CLASS.	W%	DRY DENSITY (kg/m³)	P_w (%)	L_w (%)	VISUAL CLASSIFICATION: SOIL TYPE AND COLOR
			4.7	1327			14°C
			4.5	1384			12°C
	1		4.8	1409			11.1°C
5							-7.0°C at 1.43 m
	2						
10	3						
	4						
15							
	5						
	6						

10.4.2 Thermistor Observations

Table 10.3 presents a summary of the thermistor readings and Figure Nos. 10.4 to 10.12 present the same information in graphical form. Anomalous readings can be readily identified in Table 10.3 and an approximate correction has been made to such temperatures. For example, sensor 7.0 at a depth of 6.42 m on string N1C was observed to have a resistance of 17 420 ohms on May 29, 1985 while the sensors adjacent to this sensor above and below had readings around 14 000 ohms. The temperature correction was calculated assuming the 7 was a 4 and a value of 14 420 ohms yielded a temperature of 2.5 °C. The corrected temperature was identified in the table by an "*" and was used in the generation of the figures.

TABLE 10.3

THERMISTOR READINGS

Location: N1C

Date:		85/05/02		85/05/29									
Sensor	Depth Below Ground Surface (m)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)
5.0	4.42	14820	1.9	14860	1.9								
6.0	5.42	14320	2.6	14390	2.5								
7.0	6.42	14160	2.8	17420	2.5*								
7.5	6.92	14200	2.8	14240	2.7								
8.0	7.42	14170	2.8	14210	2.8								
8.5	7.92	14030	3.0	14050	3.0								
9.0	8.42	14120	2.9	14130	2.9								
9.5	8.92	14160	2.8	14170	2.8								

Location: N1F

Date:		85/03/27		85/03/29		85/05/02		85/05/29		85/06/20		85/08/24	
Sensor	Depth Below Ground Surface (m)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)
5.0	-0.5	16570	- 0.3	16630	-0.3	10360	9.2	6470	19.2	9490	11.0	4690	26.5
6.0	0.5	19140	- 3.1	24880	-4.7*	16290	0.0	11790	6.5	15890	0.5	7910	14.9
7.0	1.5	19510	- 3.4	20170	-4.1	16790	-0.5	16430	-0.1	16460	-0.2	10010	9.9
7.5	2.0	16470	- 0.2	17820	-1.7	16550	-0.3	16500	-0.2	6780	-0.5*	11170	7.6
8.0	2.5	15620	0.9	16200	0.2	17370	-1.2	16310	0.0	16220	0.1	12200	5.8
8.5	3.0	14960	1.7	15490	1.0	16370	0.0	15900	0.5	15930	0.5	13160	4.3
9.0	3.5	13370	4.0	14760	2.0	15440	1.1	15550	1.0	15610	0.9	13930	3.1
9.5	4.0	9000	12.1	13940	3.1	14970	1.7	15830	0.6	15160	1.5	14280	2.7

* Indicates temperature observation corrected to be consistent with other results.

TABLE 10.3 (continued)

Location: N2F

Date:		85/03/27		85/03/29		85/05/02		85/05/29		85/06/20		85/08/24	
Sensor	Depth Below Ground Surface (m)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)
5.0	-0.31	13390	-0.1*	18000	-1.9	7260	16.7	5520	22.8	6530	19.0	6550	19.0
6.0	0.69	18230	-2.1	18560	-2.5	16660	- 0.4	16320	0.0	13700	3.5	9700	10.5
7.0	1.69	16300	0.0	16300	0.0	16340	0.0	16370	0.0	16370	0.0	12710	5.0
7.25	1.94	16280	0.1	16280	0.1	18640	- 0.4*	16350	0.0	16370	0.0	13380	3.9
7.5	2.44	16250	0.1	16250	0.1	16300	0.0	16380	-0.1	16350	0.0	13950	3.1
7.75	2.19	16210	0.1	16200	0.2	16270	0.1	16320	0.0	16310	0.0	14450	2.4
8.0	2.69	16110	0.3	16120	0.3	16180	0.2	16230	0.1	16260	0.1	14790	1.9
8.25	2.94	16340	0.0	16090	0.3	16160	0.2	17010	-0.8	16220	0.1	15120	1.5
8.5	3.19	16000	0.4	16010	0.4	18920	- 0.5*	16130	0.2	16160	-0.2	15340	1.2
8.75	3.44	15990	0.4	16000	0.4	16270	0.1	18120	-0.3*	16170	-0.2	15560	1.0

Location: N6A

Date:		85/05/02		85/05/29		85/06/20		85/08/24					
Sensor	Depth Below Ground Surface (m)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)
5.0	4.3	15250	1.4	15110	1.5	15140	1.5	12070	6.0				
6.0	5.3	14250	2.7	14430	2.4	14580	2.2	13280	4.1				
7.0	6.3	13790	3.3	13940	3.1	14060	3.0	13750	3.4				
7.5	6.8	13580	3.7	13710	3.5	13820	3.3	13750	3.4				
8.0	7.3	13510	3.8	13620	3.6	13710	3.5	13790	3.3				
8.5	7.8	15800	3.3*	13480	3.8	13550	3.7	13670	3.5				
9.0	8.3	13510	3.8	13600	3.6	13660	3.5	13910	3.2				
9.5	8.8	13680	3.5	13510	3.8	13560	3.7	13700	3.5				

* Indicates temperature observation corrected to be consistent with other results.

TABLE 10.3 (continued)

Location: GM2A

Sensor	Depth Below Ground Surface (m)	85/03/29 Reading (ohm)	85/03/29 Temp. (°C)	85/05/02 Reading (ohm)	85/05/02 Temp. (°C)	85/05/29 Reading (ohm)	85/05/29 Temp. (°C)	85/06/20 Reading (ohm)	85/06/20 Temp. (°C)	85/08/24 Reading (ohm)	85/08/24 Temp. (°C)	Reading (ohm)	Temp. (°C)
5.0	1.52	17060	-0.8	16560	-0.3	16450	-0.1	16270	0.1	12890	4.7		
6.0	2.52	16340	0.0	16450	-0.1	16450	-0.1	16450	-0.1	15900	0.5		
7.0	3.52	16460	-0.2	16450	-0.1	16450	-0.1	16450	-0.1	16440	-0.1		
7.25	3.77	16460	-0.2	16480	-0.2	16480	-0.2	16490	-0.2	16480	-0.2		
7.5	4.02	16210	0.1	16210	0.1	16230	0.1	16230	0.1	16440	-0.1		
7.75	4.27	16470	-0.2	16430	-0.1	16430	-0.1	16400	-0.1	16440	-0.1		
8.0	4.52	17450	-0.1*	16380	-0.1	16380	-0.1	16380	-0.1	16390	-0.1		
8.25	4.77	16430	-0.1	16310	0.0	16320	0.0	16310	0.0	16330	0.0		
8.5	5.02	16290	0.0	16250	0.1	16250	0.1	16250	0.1	16260	0.1		
8.75	5.27	16230	0.1	16230	0.1	16230	0.1	16230	0.1	16240	0.1		

Location: GM3A

Sensor	Depth Below Ground Surface (m)	85/03/29 Reading (ohm)	85/03/29 Temp. (°C)	85/05/02 Reading (ohm)	85/05/02 Temp. (°C)	85/05/29 Reading (ohm)	85/05/29 Temp. (°C)	85/06/20 Reading (ohm)	85/06/20 Temp. (°C)	85/08/24 Reading (ohm)	85/08/24 Temp. (°C)	Reading (ohm)	Temp. (°C)
5.0	-0.1	17970	-1.9	16530	-0.2	14680	2.1	11430	7.1	8440	13.5		
6.0	0.9	16040	0.4	16240	0.1	16250	0.1	16270	0.1	10610	8.7		
7.0	1.9	15010	1.7	15350	1.2	15490	1.0	15580	0.9	12890	4.7		
7.5	2.4	14720	2.0	15060	1.6	15210	1.4	15320	1.3	13600	3.6		
8.0	2.9	14400	2.5	14720	2.0	14390	1.8	15020	1.6	14170	2.8		
8.5	3.4	14160	2.8	14460	2.4	17410	-2.5*	14750	2.0	14420	2.5		
9.0	3.9	14060	3.0	14330	2.6	14500	2.3	14620	2.2	14590	2.2		
9.5	4.4	13900	3.2	14160	2.8	14310	2.6	14400	2.5	14540	2.3		

* Indicates temperature observation corrected to be consistent with other results.

TABLE 10.3 (continued)

Location: GM4A

Date:		85/03/16		85/03/27		85/03/29		85/05/02		85/05/29		85/06/20		85/08/24	
Sensor	Depth Below Ground Surface (m)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)
5.0	-0.3	17480	-1.3	16850	-0.6	18000	-1.9	10390	9.1	8960	12.1	8210	14.1	4570	27.1
6.0	0.7	16840	-0.6	16950	-0.7	16960	-0.7	16940	-0.7	12170	5.9	9520	10.9	8110	14.3
7.0	1.7	15190	1.4	15340	1.2	15360	1.2	15620	0.9	15020	1.6	12590	5.2	9730	10.5
7.5	2.2	14670	2.1	14830	1.9	14860	1.9	15140	1.5	15700	0.8	13510	3.8	10530	8.8
8.0	2.7	14160	2.8	14270	2.7	14290	2.6	14590	2.2	14730	2.0	13930	3.1	11270	7.4
8.5	3.2	13900	3.2	14010	3.0	14030	3.0	14330	2.6	14530	2.3	14160	2.8	11990	6.2
9.0	3.7	13520	3.7	13640	3.6	13710	3.5	13940	3.1	16830	-3.3*	14060	3.0	12590	5.2
9.5	4.2	13230	4.2	13410	3.9	13430	3.9	13680	3.5	15960	3.1*	31660	- 3.5*	13050	4.5

Location: GM6A

Date:		85/03/16		85/03/27		85/03/29		85/05/02		85/05/29		85/06/20		85/08/24**	
Sensor	Depth Below Ground Surface (m)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)
5.0	0.4	22650	-6.3	22100	-5.8	22370	-6.0	17450	-1.3	16060	0.3	13020	4.5	10720	8.5
6.0	1.4	20010	-3.9	20710	-4.6	19600	-3.5	17890	-1.8	17390	-1.2	17040	-0.8	15810	0.6
7.0	2.4	17210	-0.1	17900	-1.8	17730	-1.6	17650	-1.5	17360	-1.2	17220	-1.0	16640	-0.4
7.25	2.65	16720	-0.5	17740	-1.6	17440	-1.3	17540	-1.4	17420	-1.3	17220	-1.0	16660	-0.4
7.5	2.90	16590	-0.3	16960	-0.7	17010	-0.8	17220	-1.0	17080	-0.9	16970	-0.7	17040	-0.8
7.75	3.15	16990	-0.8	16750	-0.5	16790	-0.5	17040	-0.8	16980	-0.8	16910	-0.7	16990	-0.8
8.0	3.40	16620	-0.3	16650	-0.4	16670	-0.4	16890	-0.7	16810	-0.6	16850	-0.6	16860	-0.6
8.25	3.65	16650	-0.4	16670	-0.4	16670	-0.4	16760	-0.5	16810	-0.6	16790	-0.5	16800	-0.5
8.5	3.90	16690	-0.4	16680	-0.4	16690	-0.4	16700	-0.4	16750	-0.5	16720	-0.5	16770	-0.5
8.75	4.15	16560	-0.3	16580	-0.3	16580	-0.3	16590	-0.3	16610	-0.3	16620	-0.3	16760	-0.5

* Indicates temperature observation corrected to be consistent with other results.

** Assumed order, depths faded on thermistor.

TABLE 10.3 (continued)

Location: GM9B

Date:		85/05/02		85/05/29		85/06/20		85/08/24					
Sensor	Depth Below Ground Surface (m)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)	Reading (ohm)	Temp. (°C)
5.0	1.08	16070	0.3	12710	5.0	10530	8.8	8430	13.5				
6.0	2.08	16340	0.0	16390	-0.1	16300	0.0	11210	7.5				
7.0	3.08	15530	1.0	15670	0.8	15670	0.8	13400	3.9				
7.25	3.33	15300	1.3	15410	1.1	15360	1.2	13740	3.4				
7.5	3.58	15170	1.5	15280	1.3	15000	1.7	13970	3.1				
7.75	3.83	14980	1.7	15080	1.6	15460	1.1	14160	2.8				
8.0	4.08	14790	1.9	14900	1.8	15180	1.4	14300	2.6				
8.25	4.33	14490	2.4	14620	2.2	14710	2.1	14350	2.6				
8.5	4.58	14530	2.3	14670	2.1	14750	2.0	14540	2.3				
8.75	4.83	14490	2.4	14640	2.2	14670	2.1	14530	2.3				

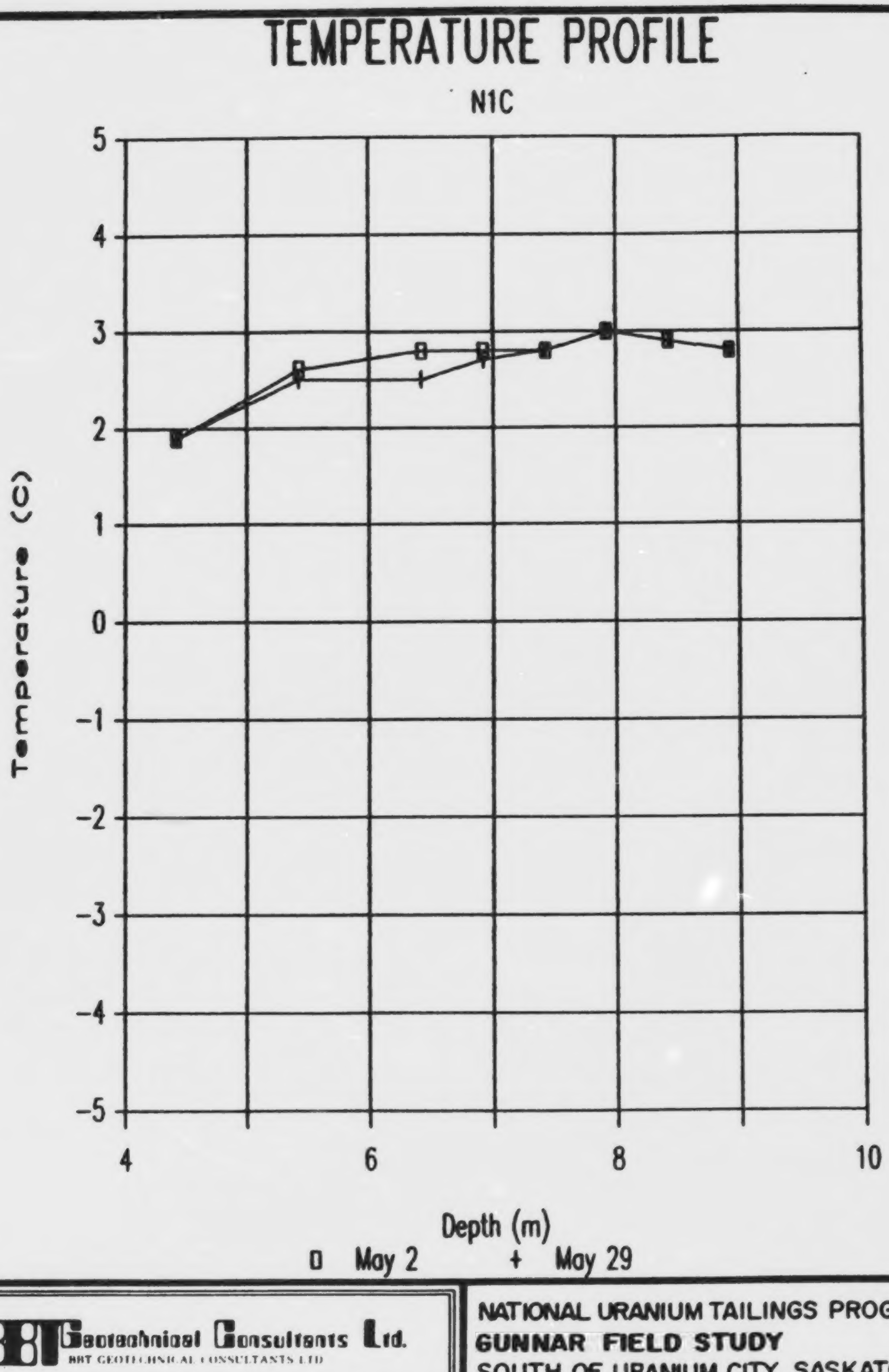


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FIGURE 10.4

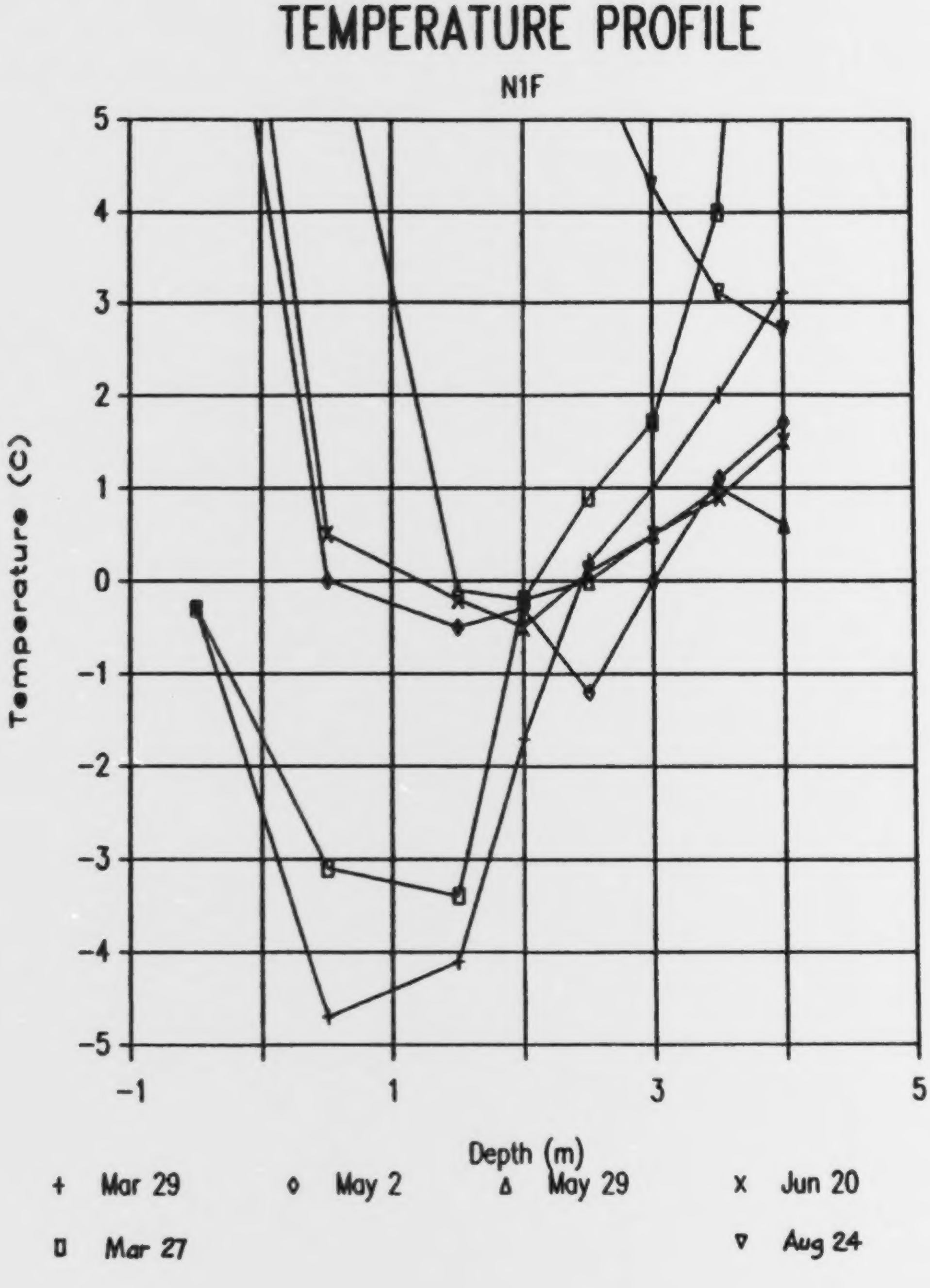

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FIGURE 10.5

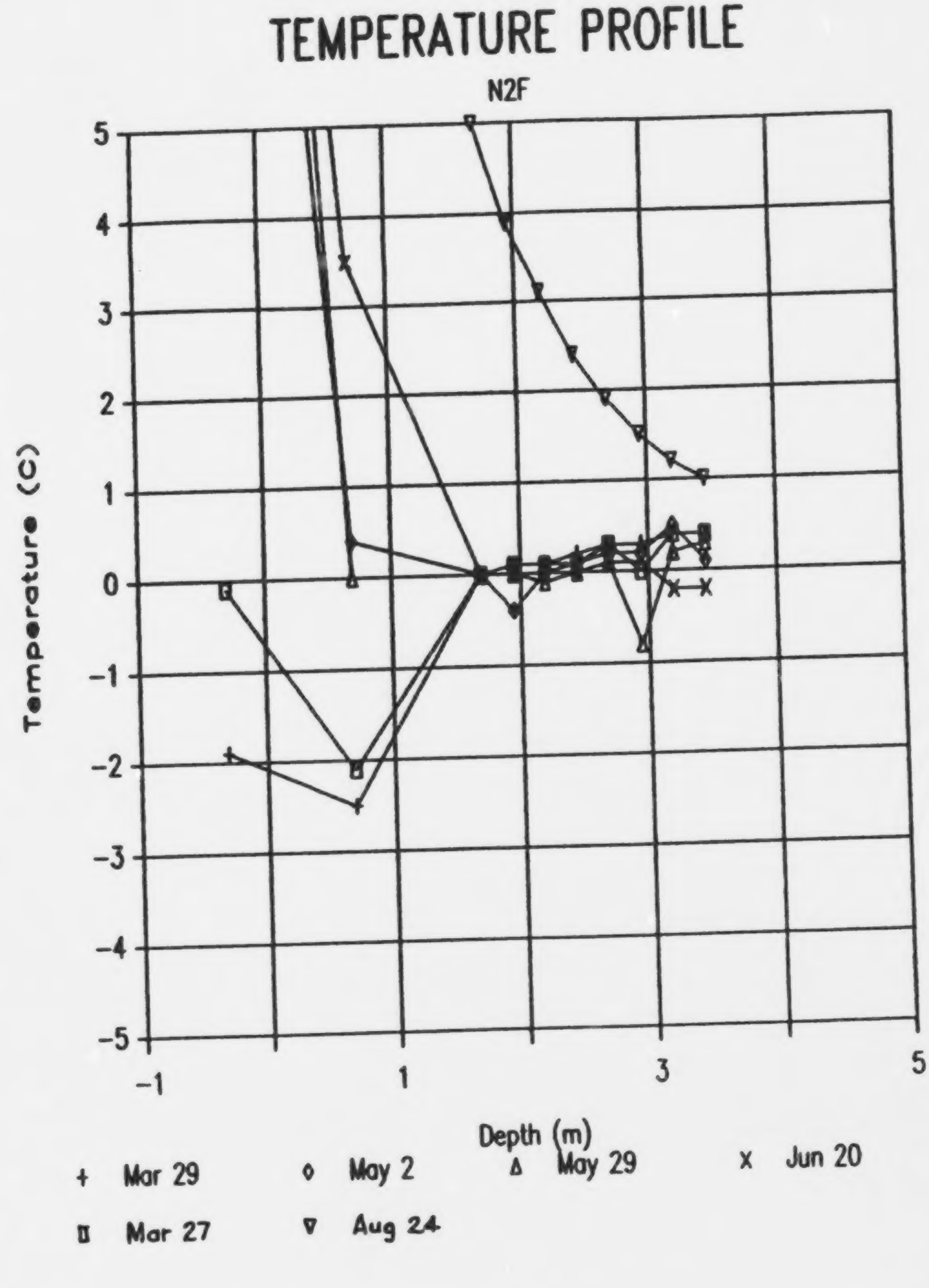

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FIGURE 10.6

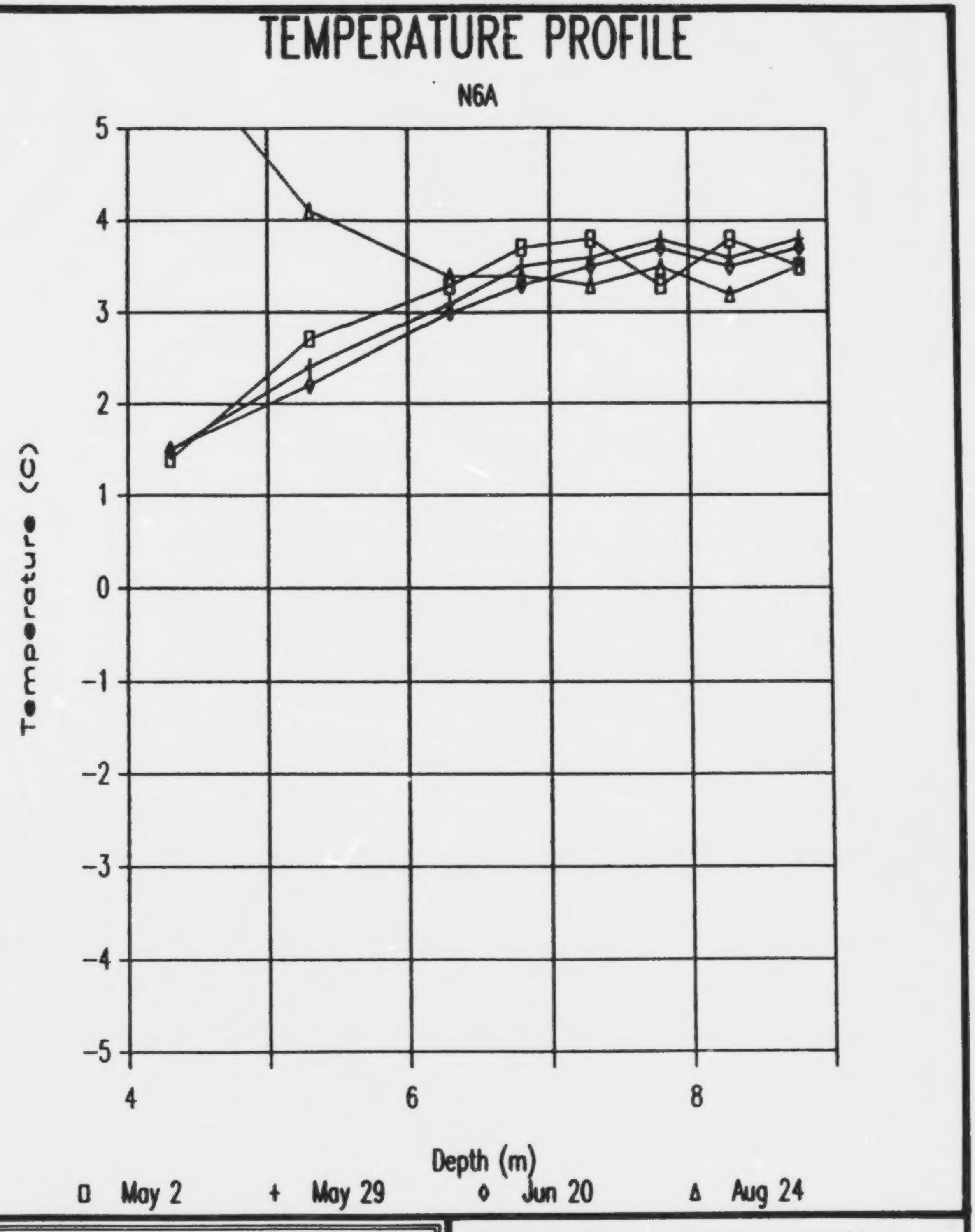

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FIGURE 10.7

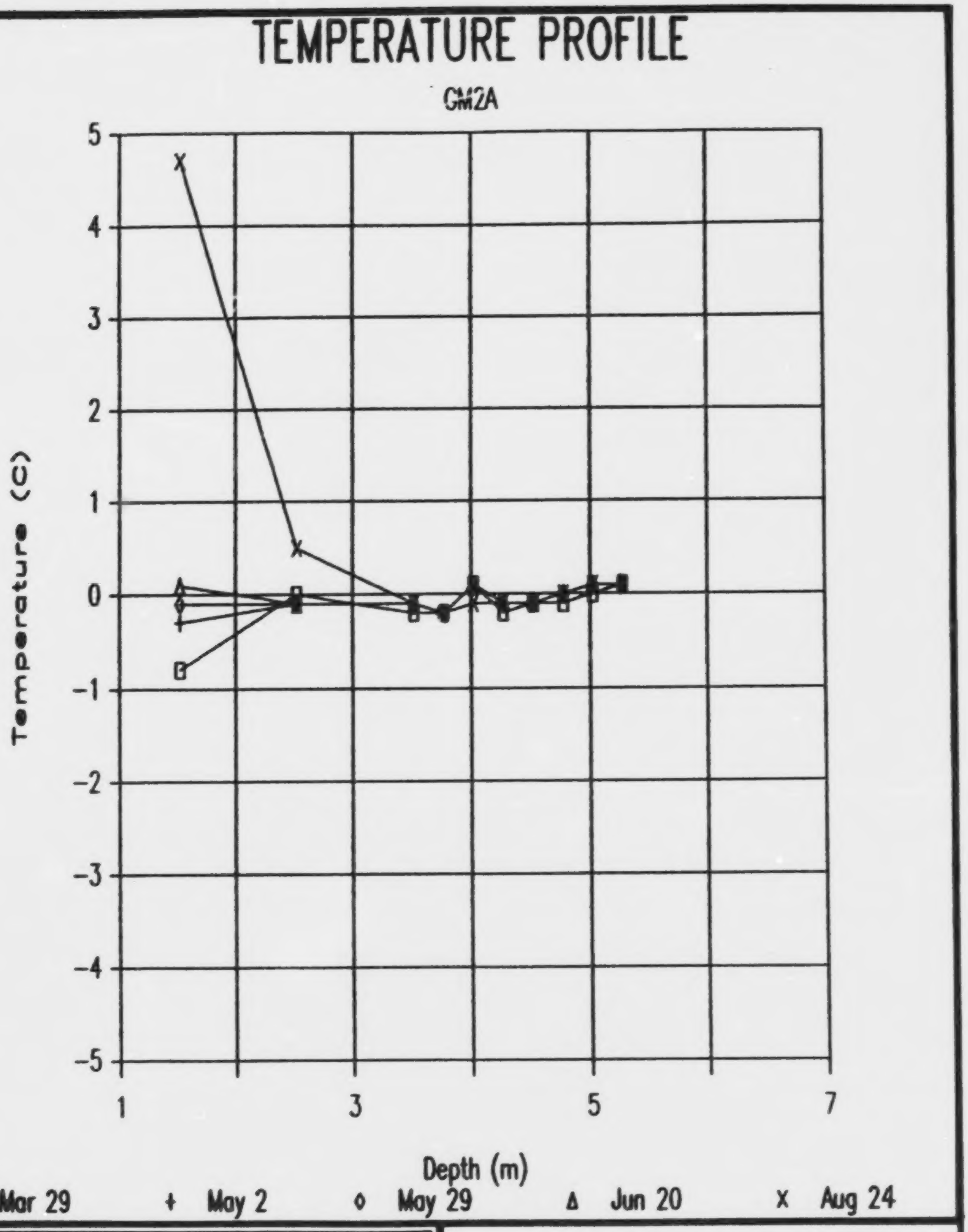

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FIGURE 10.8

TEMPERATURE PROFILE

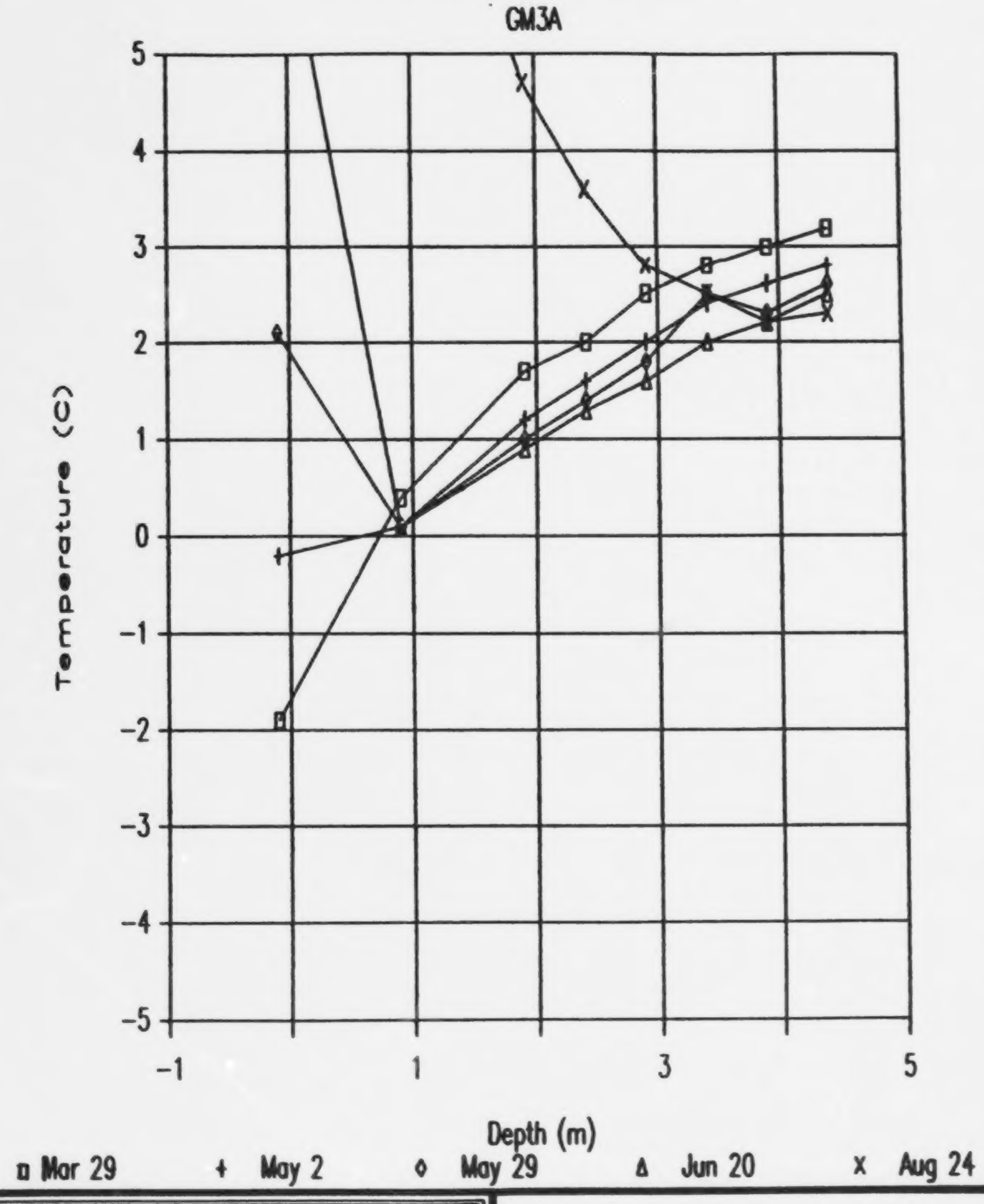

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FIGURE 10.9

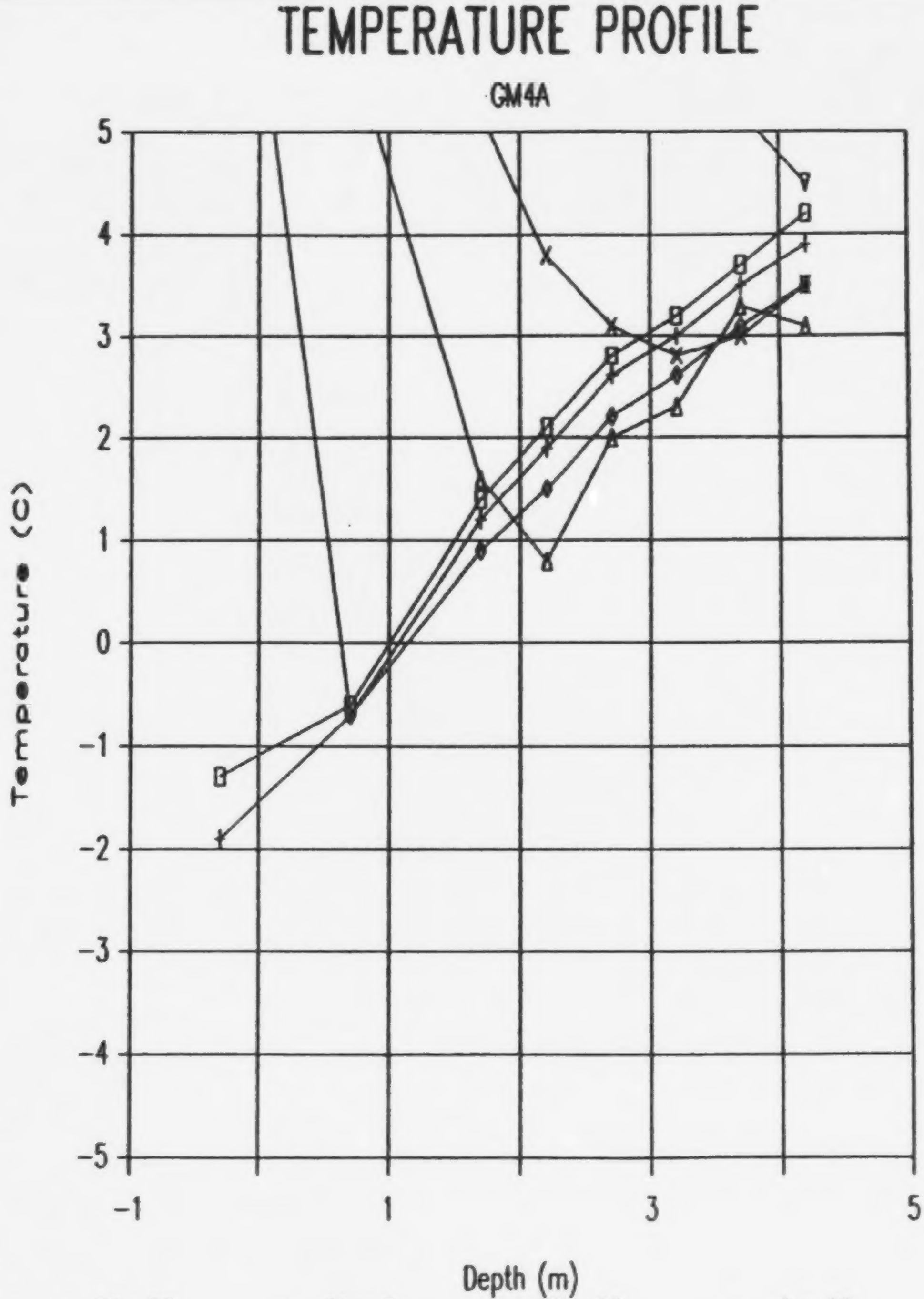

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FIGURE 10.10

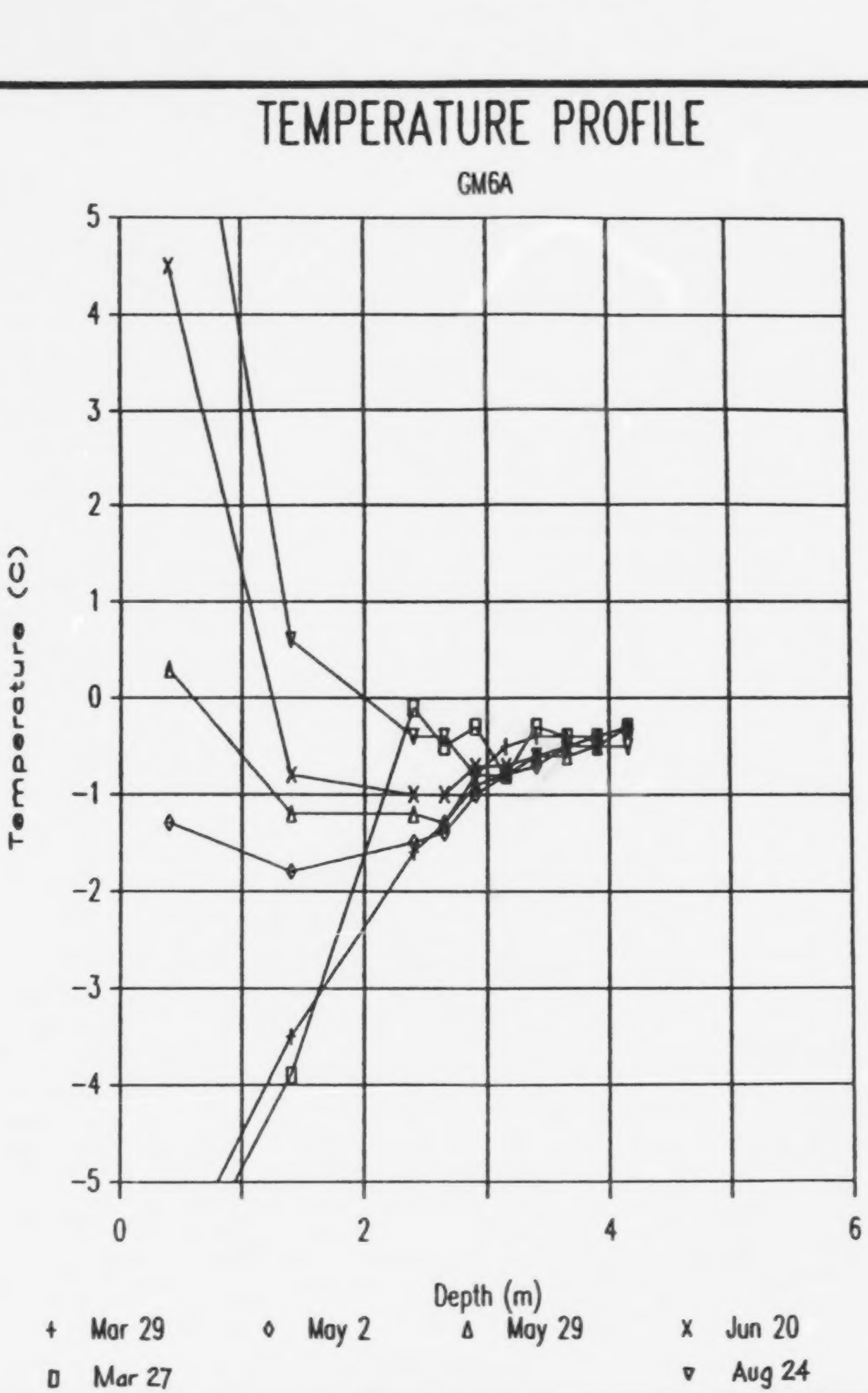

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FIGURE 10.11

TEMPERATURE PROFILE

GM9B

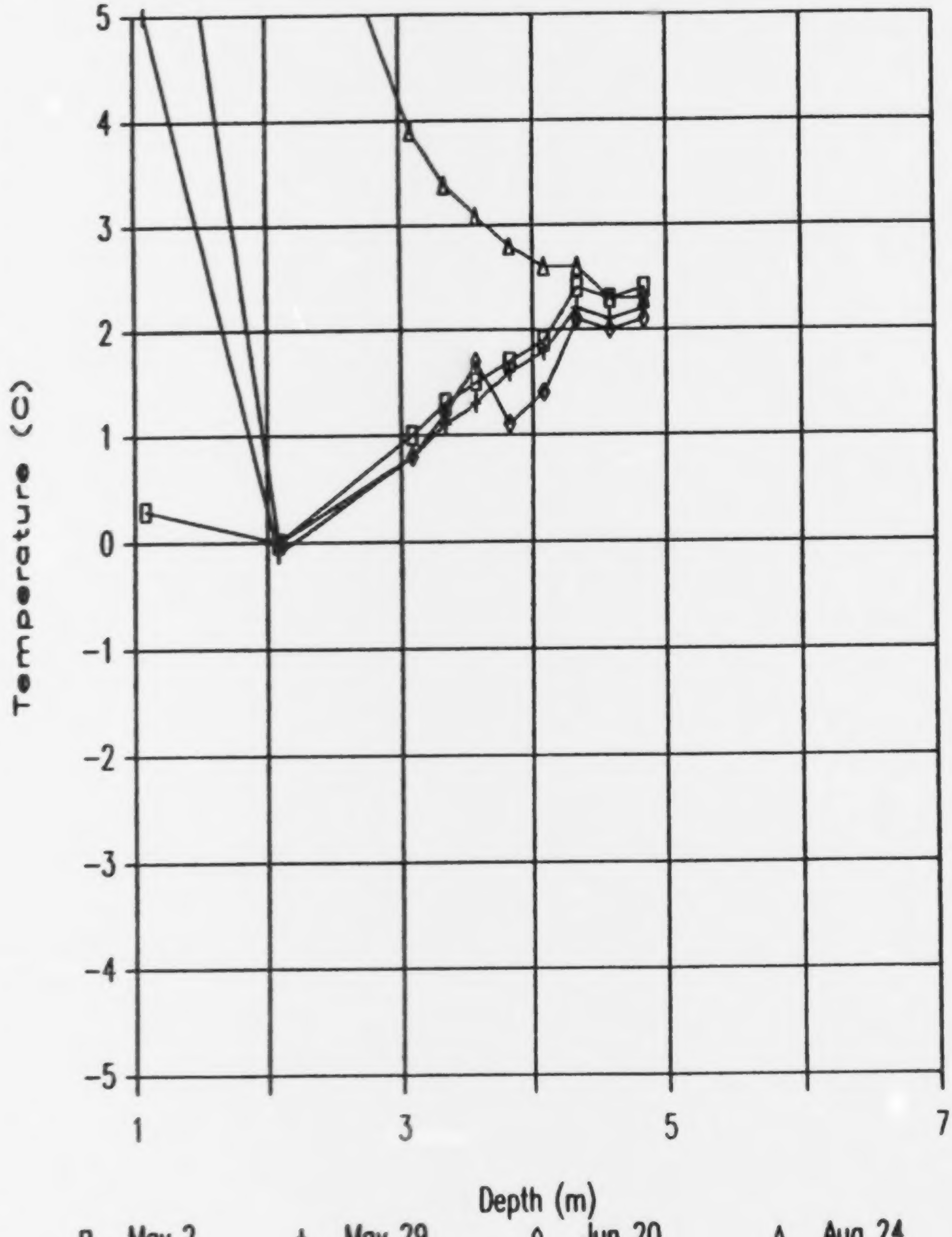

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FIGURE 10.12

10.4.3 Snow Depth Measurements

The results of snow depth measurements are presented in Table 10.4. Generally, the tops of the mounds are bare (Figure No. 10.3) and there was up to 1 m of snow in the hollows.

TABLE 10.4
SNOW DEPTHS ON EM SURVEY GRID
MARCH 1985

Station (m)	Snow Depth (m)																			
		Left Offset (m)							Right Offset (m)											
	Other (m)	200	175	150	100	50	25	0	25	50	75	100	125	150	175	200	300	400	500	OTHER (m)
-100								0.7												
-75								0.52	0.79											
-50								0.38	0.74											
-25							0.59	0.33	0.56											
0						0.7	0.52	0.49	0.48	0.64										
25								0.38												
50								0.5												
75								0.47												
100						0.49		0.34				0.45								
125								0.31												
150								0.36												
175								0.18								0.17				
200					0.78	0.48		0.23		0.27		0.45				0.3				0.63 (240)
225								0.32								0.4				
250								0.3								0.17				
275								0.7								0.33				
300	0.75 (90)					1.2		1.02	0.59	0.18	0.54	0.49	0.53	0.36	0.57	0.01	0.35			0.25 (460)
325								0.89								0.17				
350								0.74								0.26				
375								0.41								0.48				
400	1.23 (80)				0.85	0.82		0.15		0.51		0.59				0.36	0.2	0.03		0.25 (450)
425								0.14								0.22				
450								0.23								0.35				
475								0.2								0.32				
500				0.92	0.65	0.36		0.17		0.43		0.09				0.44	0.44	0.12	0.21	
525								0.32								0.12				
550								0.29								0.33				
575								0.18								0.28				

TABLE 10.4(continued)

Station (m)	Snow Depth (m)																			
		Left Offset (m)										Right Offset (m)								
	Other (m)	200	175	150	100	50	25	0	25	50	75	100	125	150	175	200	300	400	500	OTHER (m)
600		0.94				0.27		0				0.46				0.4	0.3	0.12	0.18	
625								0.42								0.38				
650								0.72								0.37				
675								0.62								0.3				
700	0.84 (250)	0.71			0.41			0.44				0.17				0.14	0.36	0.21	1	
725								0.53								0.32				
750								0.23								0.62				
775								0.1								0.8				
800		0.91			0.71			0.59	0.49	0.46	0.33	0.26	0.12	0.46	0.51	0.29	0.62	0.65	1.9	
825								0.36												
850								0.79												
875								0.62												
900			1.19		0.92			0.45												
925								0.61												

Notes:

1) Station 0+000 was at N3G, which was 1898.78 north, 4055.65 east.

2) Station 0+300 was at 1664.92 north, 3865.87 east.

3) Station 0+800 was at 1275 north, 3553.67 east.

10.5 ELECTROMAGNETIC SURVEY (P. PEHME REPORT)

This report presents the results of a geophysical survey of the Gunnar Main Tailings Basin near Uranium City, Saskatchewan. The fieldwork and interpretation of the electromagnetic (or EM) survey was subcontracted to Peeter Pehme, by BBT Geotechnical Consultants Ltd. of Saskatoon, Saskatchewan.

10.5.1 Objectives

The primary objective of the geophysical survey was to outline the occurrence and extent of ice lenses in the tailings. Secondary interests are included in Table 10.5.

TABLE 10.5

OBJECTIVES OF THE GEOPHYSICAL SURVEY

1. Occurrence and extent of ice lenses.
2. Depth of surface freezing.
3. Conductivity of the tailings.
4. Thickness of the tailings (or elevation of the underlying clay).
5. Outline of bedrock surface.
6. Stratigraphy at Langley Bay.

10.5.2 Equipment

Two instruments, the EM31 and the EM34-3 (both manufactured by Geonics Ltd.), were used for the survey. Both instruments are conductivity meters and operate on the same principle.

A primary EM field is created by passing current through a coil (the transmitter). As the EM field penetrates the ground, small currents are induced in the earth. These currents create secondary EM fields which are measured with a second coil (the receiver) on surface.

The amount of ground current induced by the primary EM field is, in part, a function of the conductivity of the material. The strength of the secondary EM field is in turn proportional to the amount of current that creates it. As a consequence, ground conductivity can be determined from the measured secondary EM field.

The instrument reading is an "apparent conductivity". The value is a weighted, average conductivity of all the layers below the instrument. Equation Eq1 was presented by MacNeil (1980) for calculating the theoretical apparent conductivity of a layered sequence.

Equation Eq1

$$\begin{aligned}\text{Apparent} &= C_1*(1-R_2) + C_2*(R_2-R_3) + C_3(R_3-R_4) + \ldots \\ \text{Conductivity} &\quad \ldots + C_{(N-1)}*(R_{(N-1)}-R_N) + C_N*R_N\end{aligned}$$

Where C_i = Conductivity of Layer i (mmho/m)

N = Total Number of Layers in the Section

R_i = Response Function of the Instrument for Layer i

$R_i = 1 / (4Z\ 2+1)\ 0.5$ Vertical Dipole Orientation Response Function

$R_i = (4Z\ 2+1)\ 0.5-2Z$ Horizontal Dipole Orientation

Where Z = (Depth to Layer i)/(Coil Spacing)

Equation Eq1 forms the basis of the interpretation. The influence a layer has on the apparent conductivity reading is a function of:

i) the layer's conductivity
ii) the layer's depth and thickness
iii) the distance between the receiving and transmitting coils
iv) the orientation of the coils (horizontal or vertical)

By varying the separation and orientation of the coils, the effective depth of penetration (summarized in Table 10.6) is controlled.

TABLE 10.6
EFFECTIVE PENETRATION DEPTHS

Intercoil Spacing (m)	**Effective Depth of Penetration (m)** **Horizontal Dipoles**	**Vertical Dipoles**
10	7.5	15
20	15	30
40	30	60

Note: At Effective Depth of Penetration R 0.35

10.5.3 The Survey

Field work was completed during the period from March 7, 1985 to March 13, 1985.

Readings were taken at 400 stations over a grid established by BBT personnel (see Figure No. 10.2). The central part of the tailings was covered by stations at 20 m intervals, along lines spaced at 25 m. The EM31 was read at waist height (see Photograph No. 10.2) in both vertical and horizontal dipole orientations, and at ground level in a vertical dipole orientation. At each station, the EM34 was read with a 10 m coil separation in both vertical and horizontal orientations. Each fourth line (i.e. 200, 300, 400, etc.), was also surveyed with a 20 m coil separation in the vertical dipole mode. Each fourth line was also extended to the east to the edge of the tailings. These extensions were surveyed with the EM34 using the 10 m coil separation (both vertical and horizontal dipoles) and a 20 m separation (vertical dipoles). Table 10.7 presents the individual readings.

The location of the grid was later provided by BBT Geotechnical Consultants Ltd.

TABLE 10.7
EM SURVEY READINGS

Station (m)	Offset Left (m)	EM 31 GV	EM 31 WV	EM 31 WH	EM 34-10 H	EM 34-10 V	EM 34-20 V
150	0	84	68.5	44	68	51.5	
150	20	90	73.5	44	69	52.5	
150	40	68	54	34	61	50.5	
150	60	65	52	32	57.5	47.5	
150	80	61.5	48.5	29	56.5	44	
150	100	54	43.5	25.9	50.5	43	
150	120	43	34	20	44	41	
150	140	42	33.5	19	42.5	36.5	
150	160	33	28	16.5	39	35.5	
150	180	37.5	29	17.2	39.5	33	
150	200	32	29	15	36.5	36.5	
175	0	68.5	53.5	30	42.5	53	
175	20	72	58.5	38	48	37.5	
175	40	61	52	30	43	47	
175	60	70	57	36	42.5	31	
175	80	56	44.5	27	38	31	
175	100	47	38	23.5	33	24.2	
175	120	41	33	21	28	28.6	
175	140	38.5	30	17	26.4	23	
175	160	32.5	25.9	15.5	22	16	
175	180	31	25	15	21.7	18.2	
175	200	37.5	29	16.2	25	23	
200	0	60	48.1	25.5	68	51.5	25.8
200	20	58.7	46.5	27	69	52.5	21.5
200	40	56.2	46	27.8	61	50.5	15.2
200	60	58	46	28	57.5	47.5	8.1
200	80	56	48	31	56.5	44	6.3
200	100	44	34.5	22	50.5	43	8.2
200	120	37	29	16.8	44	41	7.7
200	140	32	27	15.2	42.5	36.5	7.6
200	160	31	24.9	15	39	35.5	7.65
200	180	30	24.9	14.2	39.5	33	7.62
200	200	32.3	28.4	16.2	36.5	36.5	7.6
225	0	54	42	23.5	38	40	
225	20	54	41.5	24	36.5	37.5	
225	40	56	46	25.5	37	29.5	
225	60	58	47	30	39	30	
225	80	45.5	36	22	27	14.2	
225	100	25	20	10	16.2	21.5	
225	120	36	28.8	16.3	23	16.5	
225	140	30	23.8	14	21	16.8	
225	160	36	22.5	16.2	25.8	23.8	
225	180	38	31	17.5	27.8	28	
225	200	38	30	17.2	28	23	

G - Ground, W - 1 m above ground, V - Vertical, H - Horizontal

TABLE 10.7 (continued)

Station (m)	Offset Left (m)	EM 31 GV	EM 31 WV	EM 31 WH	EM 34-10 H	EM 34-10 V	EM 34-20 V
250	0	58	46	28	53.5	45	
250	20	49	38	22	51.5	48	
250	40	53.5	42	25	54.5	51.5	
250	60	56	46	28	58.5	54	
250	80	54	44	28	54	44.5	
250	100	40.5	31	18.8	47	41.5	
250	120	34	26.5	15.5	42	39	
250	140	37	28.5	15.5	43	38.5	
250	160	34.5	28	15.5	45	48	
250	180	37.5	29.7	16	44	48	
250	200	33.5	27.8	15.5	42	44	
275	0	62	48	31.5	38	21.8	
275	20	52	40	25	32	27.8	
275	40	55	44	26	34.5	29.5	
275	60	56	46	29	38	27.2	
275	80	48.2	37	23.8	35.5	36	
275	100	44	33	19.5	31	24.5	
275	120	46	34	22	30.2	27.2	
275	140	41	30	17	30	30.5	
275	160	37	30	16.5	29	28.2	
275	180	37	29	17.2	28.7	31.5	
275	200	34	26	14.2	26.5	30	
300	0	50	39.5	26.5	36.5	24.7	7.25
300	20				42.5	30	11.9
300	40				49.5	45.5	
300	60				51	43	
300	80	57.5	47	31	48	43.5	15.8
300	100	53	42	26.5	46	41	13
300	120	51	40	24.2	42.5	41	10.3
300	140	43.5	34	19.8	41	42	19
300	160	38	30	18	41.5	38.5	19.2
300	180	32	26.5	16	39	41.5	18.8
300	200	27.2	21.8	11.7	39.5	47.5	19.8
325	0	45	36	25.2	28	5.5	
325	20	64	54	38	41	27.5	
325	40	57	45	30	43	37	
325	60	60	49	30	42	41	
325	80	63	50	33	43	34	
325	100	54.5	43	26.2	35.5	40.5	
325	120	36	29.5	16.5	26.2	35	
325	140	40	32	14	28.8	28.5	
325	160	29.5	23.2	13.5	26.2	30	
325	180	31	26	14.5	24.5	28.7	
325	200	30	24	13	24.2	28.8	

G - Ground, W - 1 m above ground, V - Vertical, H - Horizontal

TABLE 10.7 (continued)

Station (m)	Offset Left (m)	EM 31 GV	EM 31 WV	EM 31 WH	EM 34-10 H	EM 34-10 V	EM 34-20 V
350	0	74	59	35.5	55.5	36.5	
350	20	82	78	42.5	69.5	52.5	
350	40	67	54	34.5	65	56	
350	60	50.5	42	25.2	55	44.5	
350	80	46	37	22.5	50.5	49	
350	100	50.5	40	23.5	54.5	56	
350	120	45	38	21.8	54	56	
350	140	43	34	19.8	55	54.5	
350	160	36	30	17.5	50	51.5	
350	180	27.2	22	11.9	42.5	48	
350	200	23.7	19	10.7	39.5	42	
375	0	71	60	42.5	47.5	36	
375	20	109	83	51	59	32	
375	40	61	50	35	45	32	
375	60	55	43.5	26.8	37	32.5	
375	80	58	47	30	39	38	
375	100	50	40.5	27	39	33	
375	120	45	38	24	30.5	39	
375	140	31	26	16.5	28	26.5	
375	160	34.5	28.5	16	27.2	35.5	
375	180	26.2	21	11.8	23.2	31	
375	200	21.7	18.8	10.6	18	22.7	
400	0	113	95.5	73	91	31.5	1.38
400	20	130	110	70.3	88.5	53	13.5
400	40	64	52	31	58.5	67	23.2
400	60	52	40.5	23.7	43.5	37.5	16.8
400	80	43.5	38	26.2	40.5	33.5	40
400	100	45	37	20.6	41.8	55.6	25.9
400	120	44	35.5	20.3	42.8	43.5	15.8
400	140	28.8	23	12.7	32.7	40.2	26.2
400	160	23.5	19.7	10.7	28.2	38	15.3
400	180	25.3	20.3	11.7	28.6	30	12.8
400	200	17.9	14	7.8	26	25.5	8.2
400	220				8.1	11.8	14
400	240				9.2	13	8.95
400	260				11	17.2	11.5
400	280				10.4	16.9	18.2
400	300				11.7	19.2	13
400	320				10.2	19	17.8
400	340				8.1	14	15.4
400	360				4.9	8.5	6.4
425	0	15.8	12.5	7.4	15.5	20	
425	20	22	18	9.8	19.2	28.2	
425	40	24.8	20	11.7	21.2	26.8	

G - Ground, W - 1 m above ground, V - Vertical, H - Horizontal

TABLE 10.7 (continued)

Station (m)	Offset Left (m)	EM 31 GV	EM 31 WV	EM 31 WH	EM 34-10 H	EM 34-10 V	EM 34-20 V
425	60	24	19.2	11.2	21.2	29.8	
425	80	31	25.2	13.5	24.5	38	
425	100	41.5	32	20.8	33	37.5	
425	120	54.5	45.5	30	41	43	
425	140	44	36	22.2	34	34	
425	160	70	56	40	53	34.6	
425	180	112	96	77	81	32	
425	200	80	65	48	59	46	
450	0	131	98.5	72	78.5	45.5	
450	20	83.3	67.5	49	60	49	
450	40	49	38	26.5	41.5	42	
450	60	42	36	24.5	37	30.5	
450	80	37	39.3	19.5	30	34	
450	100	33	26.5	16.5	28.7	31	
450	120	33.5	27	16	29	36	
450	140	30	24.5	14.5	25.5	28.7	
450	160	24.5	19.7	12	22.2	27	
450	180	20.8	16.3	10.5	18.2	24.7	
450	200	18.4	14.5	8.3	16.8	22.7	
475	0	58	47	28	40.5	50	
475	20	90	78	60	71	25	
475	40	61	49	29.5	46	45.5	
475	60	52	41	26	40	42	
475	80	35	28.5	16.5	31	43	
475	100	39.5	31.5	18.7	32	37	
475	120	34	27.8	16	28.7	33	
475	140	28.2	23.1	13	23	27	
475	160	21	17.9	10	19.8	26.8	
475	180	19	15.7	9.3	16.9	25	
475	200	17	14	8.1	15.5	22	
500	0	133	108	86	82	31	7
500	20	79	65.5	48	56	44	33.5
500	40	47	37	24	39	42	41
500	60	43	33.5	21.5	32.5	32	22
500	80	28.3	22.7	13	26.2	40	46.5
500	100	40	32	19	31.5	33.5	17.2
500	120	27.8	21.3	12	24.5	33	26
500	140	24.1	20	11.5	22.2	27	17.3
500	160	19.6	15.7	8.814			
500	180	17.4	13.8	7.3	17	23	20.8
500	200	14.6	11.9	7	15.2	22.5	23
500	220				11.2	18.7	16.7
500	240				12.2	20.5	22.4
500	260				13.2	22	22.2

G - Ground, W - 1 m above ground, V - Vertical, H - Horizontal

TABLE 10.7 (continued)

Station (m)	Offset Left (m)	EM 31 GV	EM 31 WV	EM 31 WH	EM 34-10 H	EM 34-10 V	EM 34-20 V
500	280				13	22.5	23.8
500	300				12.2	22.8	22.5
500	320				10	17.8	20.2
500	340				7.85	14	15.8
500	360				4.75	7.8	1.18
500	380				3.15	4.95	5.3
525	0	110	92	65	65	43	
525	20	135	110	85	76	17.2	
525	40	38	31	19.8	34	42.5	
525	60	47	39	22.8	35.5	39	
525	80	43	33.5	20.8	35.5	34	
525	100	35.5	29.3	18.8	29	39	
525	120	31	26	14.2	25.8	35.5	
525	140	23	18.5	10.2	21.5	30	
525	160	18.8	15.5	9.1	18.3	23.7	
525	180	17.2	14	7.8	16.8	22.2	
525	200	14.9	12.3	7.2	15.8	23.5	
550	0	94	75	48	55.5	30	
550	20	46	36	21.5	35	38.5	
550	40	41	34	20	28.2	27.8	
550	60	45	37.5	20	32.5	44.5	
550	80	48	38.5	21.3	35.5	42	
550	100	34	34.5	19	34	46	
550	120	31	26	13.9	27.5	34	
550	140	26.2	21	11.4	24	31	
550	160	23.2	19.2	10.7	20.8	29	
550	180	20	16.7	9.3	19	26	
550	200	18.5	15	8.7	17.5	27.5	
575	0	50	39.5	23.8	34	52	
575	20	46	37.5	25.5	39	41	
575	40	40.5	32	19.2	32	36	
575	60	30.2	24.8	15.5	28.5	33	
575	80	32	26	16	29	35	
575	100	37	29.4	16.7	29.5	35	
575	120	33	27	15.5	30	35	
575	140	27.2	22	12	25.3	35	
575	160	21.7	17.8	10	21.2	32.5	
575	180	21	17.5	10	20	27.4	
575	200	18.7	15.5	9.1	19.1	29.5	
600	-120	84	66	39.5	56.5	56	19.4
600	-100	84	70	43	58	53	13.4
600	-80	73	58	36	59	70	43
600	-60	150	129	89	97	24	11
600	-40	78.9	62	34	59	79	45

G - Ground, W - 1 m above ground, V - Vertical, H - Horizontal

TABLE 10.7 (continued)

Station (m)	Offset Left (m)	EM 31 GV	EM 31 WV	EM 31 WH	EM 34-10 H	EM 34-10 V	EM 34-20 V
600	-20	50	40	25	38	50	46
600	0	39.5	29	15	27.6	53.5	45
600	20	29.1	22.9	17.7	32.5	38	49
600	40	37.5	29.3	19.5	31	32	34
600	60	36.5	29.8	17.3	31	38	27
600	80	36	29.3	16.5	29.5	38	37
600	100	38	30	17.2	30	36	27.8
600	120	33	26.6	14.5	28.2	40	28.5
600	140	29	22.8	12.2	25.7	38	27.1
600	160	25.7	21	11.2	24.2	34.5	24.1
600	180	21.5	17.3	9.5	21.9	31.5	24.2
600	200	19	15	8.5	18.5	30	25.2
600	220				16.5	25.8	29.5
600	240				17.5	26	28.8
600	260				16	25	31
600	280				15	26.5	30
600	300				13.2	24.5	29
600	320				11	19	22.2
600	340				7.2	12.2	12.5
600	360				3.95	5.8	1.32
625	-120	119	91	57	79	65	
625	-100	159	120	80	93.5	43.5	
625	-80	85.5	67	39	64	67.5	
625	-60	98.5	77.5	50.5	73.5	67	
625	-40	83	69	49	64.5	50	
625	-20	59	46	29.2	47.5	57.5	
625	0	49.5	39.5	24.2	42	50	
625	20	43	34.5	22	33	39.5	
625	40	25.5	21.2	12	23.2	46	
625	60	41.5	33	19	29.8	38	
625	80	26	21.8	12	24.4	38	
625	100	29.8	24.2	13.7	27.8	45	
625	120	36	29.8	18	30	37	
625	140	33.5	27.5	16.5	29.5	38.5	
625	160	30.5	25	14	27.2	33	
625	180	26.2	21.5	12	25.2	34.5	
625	200	20.1	17.1	9.2	21	33	
650	-120	105	85	48	79	65.5	
650	-100	86	70	42	86	54.5	
650	-80	100	79	49	72	58	
650	-60	95	73	42.5	71	77	
650	-40	96	82	52	70.5	48.5	
650	-20	115	105	69	78.5	13.9	
650	0	63	50	28	51.5	59	

G - Ground, W - 1 m above ground, V - Vertical, H - Horizontal

TABLE 10.7 (continued)

Station m	Offset Left-m	EM 31 GV	EM 31 WV	EM 31 WH	EM 34-10 H	EM 34-10 V	EM 34-20 V
650	20	63	52	31.5	43	44.5	
650	40	49.5	39.5	24.8	38.5	43	
650	60	47	38.5	23.8	34.5	44.5	
650	80	44.5	35.5	22	35.5	38.5	
650	100	37.5	30	18	30	33.5	
650	120	27.5	22.2	13	25.5	36	
650	140	28	22.8	12.4	22.7	30	
650	160	31	25.8	14.7	25.8	33	
650	180	29	23.3	12.7	25.4	32.5	
650	200	23.8	19.8	11	22.4	33.5	
675	-120	116	92	62	81	65	
675	-100	139	109	74	85	64	
675	-80	140	113	76	89	60	
675	-60	172	133	88	95.5	67.5	
675	-40	128	110	82	83	65	
675	-20	69.5	56.5	34	54	70.5	
675	0	68.5	54	32	52	56	
675	20	74.5	58	37	51	43.5	
675	40	77	60	43	58	42.5	
675	60	48	38	22.5	36	42	
675	80	41.5	34	21.2	33	41	
675	100	56	29.5	18.5	31	33	
675	120	34	27	17	27	28	
675	140	29	23.5	12.8	22.7	31	
675	160	32	26.2	15	26.2	31.5	
675	180	25	20.4	11.2	22.5	37.5	
675	200	24	19.7	10.2	22.2	38	
700	-120	130	110	64	88	71.5	
700	-100	190	142	90	108	83	38
700	-80	172	145	89	98	70	36
700	-60	137	119	85	93	44	41.5
700	-40	125	104	65	80	62	51.5
700	-20	76	60	30	55	79.5	49.5
700	0	66	53.5	30			42
700	20	67.5	54	33.5	51	48	40
700	40	43	36	21.7	41	52.5	32
700	60	57.5	44	31	47.7	36.5	31.5
700	80	47.5	33	22.2	37.5	33	28.3
700	100	44	34	21	31.5	27.5	22.2
700	120	36	47	22	32.5	29.5	23
700	140	44	34	21.5	31.5	31	25.8
700	160	33.5	27	16	26	27.5	17
700	180	30.5	24.2	12.3	21.5	35	35
700	190	28.5	22.8	12.8	24.8	32	33

G - Ground, W - 1 m above ground, V - Vertical, H - Horizontal

TABLE 10.7 (continued)

Station (m)	Offset Left (m)	EM 31 GV	EM 31 WV	EM 31 WH	EM 34-10 H	EM 34-10 V	EM 34-20 V
700	200	27	21.7	12	24.5	35	30.5
700	220				25.5	32	39
700	240				19.8	31	32
700	260				19	29.5	28.8
700	280				17.4	28	29.5
700	300				16.8	28	27
700	320				16.6	26.5	23.1
700	340				12.5	20.2	16
700	360				7.85	15.5	8.75
725	-120	132	108	73	94	77	
725	-100	148	123	90	97	88	
725	-80	103	82	58.5	78	54	
725	-60	81.5	64	38	62	64	
725	-40	82	63	35	56	62	
725	-20	70	57.5	39	60	51	
725	0	75	60	37	53	65	
725	20	65.5	51.5	32	48.5	46	
725	40	65	51	33	46	45	
725	60	35.5	28.9	15.4	26	54	
725	80	57.5	46	29.3	42.5	34	
725	100	47	38.5	25	37	43	
725	120	37.5	31.5	19.7	32	30	
725	140	34	28.9	14.8	26.8	38.5	
725	160	35.5	28.7	16.8	30.5	37	
725	180	37	29.8	17.5	30	38.5	
725	200	28.9	23.2	12.5	23.5	40	
750	-120	160	122	70	94	73.5	
750	-100	150	118	67	86	64	
750	-80	89	68.5	38	66	73	
750	-60	93	72	40	64	68	
750	-40	79	64	38	60	65	
750	-20	72	58	33	56	63	
750	0	70	57	33	53.5	50	
750	20	68	54	33.5	51.5	52	
750	40	73	57.5	36	52.5	58.5	
750	60	73	58.7	36	54.5	54.5	
750	80	63.5	50.5	31	51.5	49.5	
750	100	54	44	26.2	45	42.5	
750	120	35.5	34.5	21	34	42	
750	140	45.5	36	24.5	38	43	
750	160	41	32	17.3	32	43	
750	180	41	32	18.5	32	40	
750	200	36.5	32	16.5	30.5	41	
775	-120	187	140	89	120	68	

G - Ground, W - 1 m above ground, V - Vertical, H - Horizontal

TABLE 10.7 (continued)

Station (m)	Offset Left (m)	EM 31 GV	EM 31 WV	EM 31 WH	EM 34-10 H	EM 34-10 V	EM 34-20 V
775	-100	160	130	88	100	70	
775	-80	22.5	71.5	45	20.5	63.5	
775	-60	81	64	39	60.5	59	
775	-40	68	53	31.5	54.5	53.5	
775	-20	73	58.5	38	58.5	54	
775	0	77	61	37	58	62	
775	20	75.5	60	38	58	54	
775	40	71.5	56	33.5	56	66	
775	60	72.5	58	36	53	57	
775	80	76	60.5	39.5	56	45.5	
775	100	69.5	54	32.5	52	62	
775	120	60.5	47.5	29.5	50	42.5	
775	140	64	51	30	48	46	
775	160	50	39.5	31	55	37.5	
775	180	44.5	36	21	39	48.5	
775	200	33.5	27.4	15.2	31.5	40.5	
800	-120	142	110	71	94	64	32
800	-100	145	112	73.5	91.5	53	25
800	-80	91.5	70.5	44	66	67	54
800	-60	78	61	37	57	63.5	50.5
800	-40	75	59.5	36.5	57	62	48
800	-20	77.5	76	45.5	61	52	42
800	0	69.5	56	35	54.5	30	41
800	20	71	56	34	53.5	54.5	47.5
800	40	70.5	52.5	36	52.5	55.5	54.5
800	60	66	52	33	49	54	41.5
800	80	58	46	27.8	45.5	53	41
800	100	52.1	41	24.2	41	52	88
800	120	44	20.5	20.5	35	48	39
800	140	40.5	32.5	19.5	31	43	33.5
800	160	37	30	17.1	28.7	37.5	25.2
800	180	38	31	17	27.2	40	44
800	200	26.5	24	16	46.5	19.6	
0	0	76	58	37			13
10	0	80	64	44	51.5	38	
20	0	88.5	73	46	53.5	55	9.25
30	0	92	75	48	56.5	32	
40	0	86	72	43	54.5	49.5	26.8
50	0	87	74	47	56.5	43.5	
60	0	96	76	48	59.5	47.5	23.9
70	0	94	75	49	61	43	
80	0	90	73	46.5	59.5	40	23.4
90	0	89	74	52	61	27.3	
100	0	76	63.5	39.5	57	45.5	28.5

G - Ground, W - 1 m above ground, V - Vertical, H - Horizontal

TABLE 10.7 (continued)

Station (m)	Offset Left (m)	EM 31 GV	EM 31 WV	EM 31 WH	EM 34-10 H	EM 34-10 V	EM 34-20 V
110	0	69	56	36	48	46	
120	0	71	58	38	50	43	27
130	0	83	65	40	53.5	42	
140	0	84	67	45.5	55	41	22.3
150	0	83	70	45	55	46	
160	0	85	70	43.5	53.5	41	18.2
170	0	75	60	37.5	49.5	40	
180	0	68	54	30.5	42	51.5	27.5
190	0	65.5	51.5	30.5	43.5	38	
200	0	67	53	29.5	40	44	14.3
210	0	61	48	26.5	40	42	
220	0	55	43	24	37.5	39	23.5
230	0	57.5	45.5	26.8	38.5	38	
240	0	56	48	35	44	26	12.9
250	0	62	48.5	28.5	42	35	
260	0	64	52	31	40	34	12
270	0	65.5	53.5	34.5	46.5	24.5	
280	0	60	47	30	39	22.2	
290	0	46	36	22.2	30.5	14	
300	0	38.5	31	18.2	23.5	20.3	10
310	0	36	29	18.3	22.2	16.8	
320	0	40.5	32.5	23.4	26.8	14	9.6
330	0	52	40.5	27.3	33.3	14.7	
340	0	67.5	54	34	38	21.7	
350	0	74	59	36	42	26.5	
360	0	71	56	35	44	30	11.5
370	0	73	59	35.5	45	39	
380	0	76	60	37.5	49	34.5	19.2
390	0	90	71	43	56	42.5	
400	0	100	88	61	64.5	16	9
410	0	102	83	52.5	71.5	51	
420	0	88.5	70	47	66	37	11
430	0	69	58	41.5	53	32	
440	0	70	55.5	35	55	53	37
450	0	120	102	68	65	28	
460	0	132	108	72	75	7.4	
470	0	78	62.5	35	52.3	56	
480	0	60	47.5	30	47.5	43	57
490	0	86	70	48	61	50	
500	0	130	113	77.5	76	20	
510	0	143	120	84	86	30.5	
520	0	130	105	70	83	36	24.3
530	0	105	92	70.5	84	33.5	
540	0	103	88	68.5	86	33.5	15.5

G - Ground, W - 1 m above ground, V - Vertical, H - Horizontal

TABLE 10.7 (continued)

Station m	Offset Left-m	EM 31 GV	EM 31 WV	EM 31 WH	EM 34-10 H	EM 34-10 V	EM 34-20 V
550	0	102	82	55	70	39.5	
560	0	76	60	40.5	59	35.5	25.5
570	0	52	42	26.5	47.5	45.5	
580	0	62.5	49	27.3	39	34.5	38
590	0	58	45	28.8	39.5	51.5	
600	0	35.5	28.9	45	30	41.5	40.5
610	0	50	40	22.7	32.5	26	
620	0	54.5	43	24.8	41.3	44	39.5
630	0	55	42.5	24.2	42.5	58.5	
640	0	61	48	28	46	42	45
650	0	63	52	30	47	54.5	
660	0	63	50	30	50	49.5	47
670	0	70	54.5	32.5	50	48.5	
680	0	68	54	31.5	49.5	54.5	43.5
690	0	65	52	30	50	47	
700	0	68	54	31.5	49.3	50	50
710	0	71	57.5	34	52	56.3	
720	0	72	58	36	55	52.5	40
730	0	72	58	34	56	63.5	
740	0	74	60	38	55.5	58	47
750	0	70	56	34.5	56	56	
760	0	73	60	40	56	55	52.5
770	0	75.5	62	38	55.5	59.5	
780	0	73.5	61.5	38	54.5	50	43.5
790	0	71.5	56.5	33	54	54.5	
800	0	69.5	56	36	54	50.5	51.5
810	0	74	57.5	34	56.5	54	
820	0	78	63	38.5	58	57.5	36
830	0	74.5	60	39	57	56	
840	0	74	63	37.5	59.5	47	34
850	0	66	52	32	50	53.5	
860	0	60.5	48	30	46.5	48.5	37.5
870	0	65	52	32	46	42	
880	0	64	50.5	30	45	42	11.5
890	0	60	49.5	30.5	38	27.5	
900	0	43	35	22.5	29	19.5	
910	0	24.5	19	13.5	16	13.5	
920	0	8.7	6.7	5.1	5.5		
LB EAST	40	72.5	53	24.5	52.5	23.3	15.5
LB	20	71	40.5	59.5	46.5	47.5	16.7
N5	0	61.5	53.5	51.5	39	36	16.8
LB	20	49	24.7	38	31	27	12.5
LB WEST	40	37	17.2	29	25.5	28.9	9.7

G - Ground, W - 1 m above ground, V - Vertical, H - Horizontal

10.5.4 Interpretive Approach

The stratigraphy of the site is summarized in Figure No. 10.13. The stratigraphic layers of similar conductivities are combined to create a "Conductivity Section" which is used in the interpretation.

The upper layer (Layer 1 of the conductivity section) is comprised of snow, frozen tailings and any unsaturated tailings that may exist. The material conductivity is very low, 0.1 mmhos/m is used in all modeling.

The second conductivity unit (Layer 2) represents saturated tailings. This layer almost totally dominates the response of the instruments and has an average conductivity of approximately 230 mmhos/m.

A "silty clay" (Layer 3) with a conductivity of approximately 10 mmhos/m underlies the tailings.

The bottom unit (Layer 4) is bedrock and its conductivity is assumed to be 0.1 mmhos/m.

The dominating affect of the tailings on the instrument readings makes interpretation difficult. A small change in Layer 2 of the model has a significant effect on the theoretical instrument response (see Table 10.8). Relatively large changes in the conductivity of Layer 3 are required to significantly affect instrument response. The instruments are also insensitive to changes in depth to bedrock.

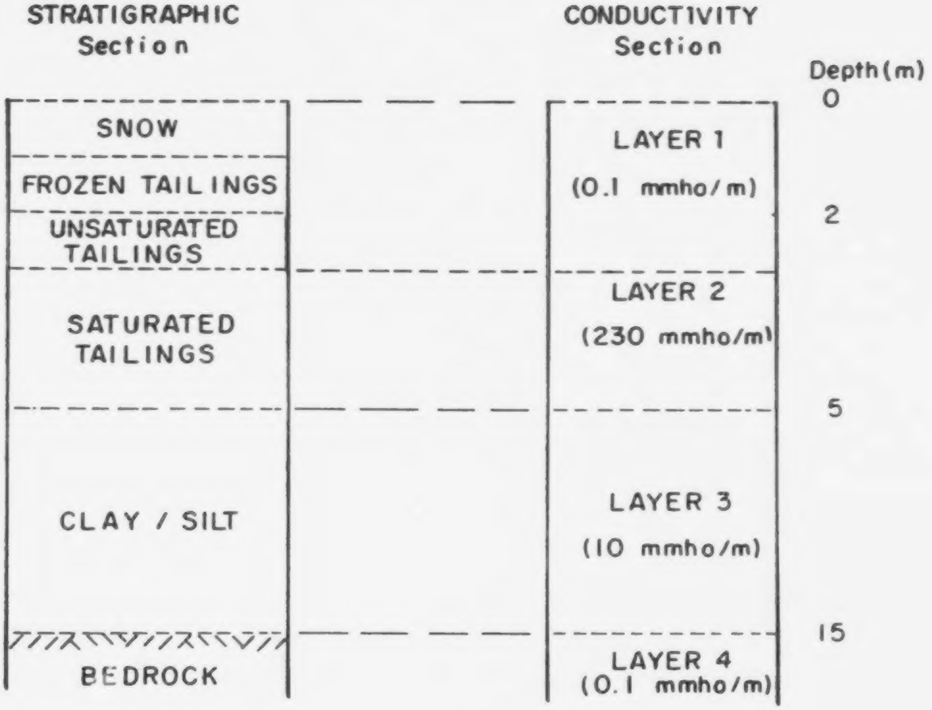

STRATIGRAPHIC Section
CONDUCTIVITY Section
Depth(m)
0
2
5
15
SNOW
FROZEN TAILINGS
UNSATURATED TAILINGS
SATURATED TAILINGS
CLAY / SILT
BEDROCK
LAYER 1 (0.1 mmho/m)
LAYER 2 (230 mmho/m)
LAYER 3 (10 mmho/m)
LAYER 4 (0.1 mmho/m)

Figure 10.13 Schematic Stratigraphic and Conductivity Section

TABLE 10.8

INFLUENCE OF CHANGING MODEL ON INSTRUMENT RESPONSE

Model			Percent Change in Instrument Reading				
			EM31		EM34-10		EM34-20
Layer	Change		Horizontal	Vertical	Horizontal	Vertical	Vertical
2	Conductivity	- 10%	- 9.8	- 9.7	- 9.5	- 9.3	- 8.6
2	Depth	- 10%	14.1	11.1	9.4	5.1	3.4
3	Depth	- 10%	- 8.2	- 9.3	-10.8	-14.6	16.7
3	Conductivity	+100%	2.4	2.9	4.0	7.1	14.6
4	Depth	- 16%	0.2	0.3	0.5	1.0	3.0

In the field, the instruments are read to within approximately 5 percent of the theoretical apparent conductivity. This discrepancy results from coil misalignment and the precision of the instrument. As a consequence of the high sensitivity to Layer 2 and reading errors, it was often difficult to find a model that fit all the instrument readings simultaneously at a station. This complicated the interpretation procedure and forced a time-consuming "hands-on" type of analysis for much of the data. The interpretation went as follows:

1) From a comparison of instrument readings at N3 and N6 to theoretical responses for the sections, the conductivity of the tailings was concluded to be both dominant and variable. The conductivity of Layer 3 was estimated to be 10 mmhos/m.

2) EMITTER (a program that adjusts a model to fit field data) was used to vary the top, bottom and conductivity of Layer 2 in the model to fit the data at each station. Due to the dominance of the tailings, iterations would not converge to a satisfactory solution at most of the stations. However, over 100 of the stations did converge, and these were used to calculate an average conductivity for Layer 2 of 230 mmhos/m.

3) With the conductivity of Layer 2 fixed, a new model was developed with an extra layer between Layers 1 and 2. The additional layer was designed to allow for the possibility of an unsaturated zone. The top, bottom and conductivity of the extra layer was allowed to vary according to the readings from EM31 (horizontal and vertical dipoles) and the EM34 (10 m, vertical dipole). The analysis was repeated without the extra layer. The top and bottom of the tailings were adjusted according to the EM31 readings. Stations where the 2 analyses gave similar results were considered solved.

4) At some stations, Step 3 resulted in a solution for the depth to the tailings, but no agreement on the bottom or conductivity of Layer 2. For these stations, these latter 2 parameters were readjusted according to pairs of instrument responses. The results from the pairs used (EM31 horizontal and vertical, EM34-10 horizontal and vertical, and EM31 vertical with the 34-10 horizontal) were compared to consistent solutions picked.

5) Approximately 1200 theoretical models were calculated by systematically varying the top, bottom and conductivity of Layer 2. For each unsolved station, the theoretical results were compared to these models. In cases where a good fit could not be found, new models were calculated until an acceptable fit was obtained.

6) The results were plotted and irregularities in the plots were double-checked for alternative solutions that were consistent with the surrounding stations.

7) Bedrock depths were determined by varying the depth of Layer 4 according to the EM34-20 reading and the interpretations for the upper layers at each station.

10.5.5 Results

The results of the survey are separated into discussions for each of the objectives. Table 10.9 shows the results of the interpretation of the EM survey by station.

10.5.5.1 Ice Lensing

The effect of a 0.1 m thick ice lens on the base model is shown in Figure No. 10.14. Since the lenses observed to date were only a few centimeters thick, Figure No. 10.14 represents a maximum influence on the reading. The effect of the lenses on the instrument readings is much less than the effect of varying the parameters of Layer 2 in Table 10.8. Considering the possible 5 percent error in the instrument readings, little confidence can be placed on any prediction of ice lensing.

10.5.5.2 Thickness of Layer 1 (Figure No. 10.15)

The calculated thickness of Layer 1 represents frost plus the thickness of snow cover over most of the area. An unsaturated zone may be included in the thicker areas of the southeast part of the site, but this cannot be confirmed from the existing data. Over most of the area, approximately 1 m of the reported value is snow. However, localized areas existed without snow cover (see Figure No. 10.15). Due to this variability, a simple subtraction of the snow cover is not possible. The accuracy of the reported value for the thickness of Layer 1 is from 0.5 to 1.5 m over the site.

The thickness of Layer 1 tends to increase to the southeast, roughly paralleling surface topography. Some locally thick areas (up to 5 m) of Layer 1 (for example Area "A" Figure No. 10.16), correspond to mounds on the tailings surface without snow cover. (The location of "ice mounds" and exposed tailings noted during geophysical survey are included on Figure No. 10.2).

TABLE 10.9
EM SURVEY INTERPERTATION BY STATION

Station (m)	Offset Left-m	Layer 2 Depth (m)	Layer 2 Cond.	Layer 3 Depth (m)	Surface Elev. (m)	Layer 3 Elev. (m)
150	0	2	191	5.2	97.9	92.7
150	20	3.4	210	4.9	95.8	90.9
150	40	2	180	4.6	97.9	93.3
150	60	3	200	4.7	998.7	99.4
150	80	4	220	4.5	99.4	94.9
150	100	3.5	180	5.1	99.9	94.8
150	120	4	220	4.8	100.1	95.3
150	140	4	230	4.9	100.5	95.6
150	160	5.5	235	4.6	100.9	96.3
150	180	5	230	4.5	101	96.5
150	200	4	280	4.9	102	97.1
175	0	2.9	200	6.1	97.1	91
175	20	1.8	268	4.5	98	93.5
175	40	2.6	170	6	917.9	911.9
175	60	2.2	350	3.3	98	94.7
175	80	2.2	170	4.3	99.3	95
175	100	2.1	145	3.8	99.9	96.1
175	120	2.9	180	5	100.5	95.5
175	140	3	190	4.5	101	96.5
175	160	3.5	190	4	101.1	97.1
175	180	2.6	230	3.4	101.4	98
175	200	3	313	3.8	101.8	98
200	0	3	184	7.3	98.3	91
200	20	2.8	230	4.9	98.1	93.2
200	40	2.5	160	6	97.9	91.9
200	60	2.7	230	4.7	99.1	94.4
200	80	2.1	230	3.5	99.5	96
200	100	2.7	130	5.5	100	94.5
200	120	4	190	6.5	100.7	94.2
200	140	3.4	170	5.3	101.1	95.8
200	160	3.5	170	5.5	101.2	95.7
200	180	4	240	5.5	101.5	96
200	200	3.3	230	4.9	101.3	96.4
225	0	3	190	5.5	98.6	93.1
225	20	2.6	150	5.6	97.7	92.1
225	40	3	230	5.9	98.8	92.9
225	60	2.3	230	4.1	99.2	95.1
225	80	2	125	4	99.9	95.9
225	100	4	220	5	100.4	95.4
225	120	2	150	4	100.9	96.9
225	140	4	190	6	101.2	95.2
225	160	2.4	155	4	101.4	97.4
225	180	3	165	4.8	101.6	96.8
225	200	2.7	190	4	101.8	97.8

TABLE 10.9 (continued)

Station (m)	Offset Left-m	Layer 2 Depth (m)	Layer 2 Cond.	Layer 3 Depth (m)	Surface Elev. (m)	Layer 3 Elev. (m)
250	0	3	230	4.7	98.7	94
250	20	2.7	230	5	99	94
250	40	2.6	267	5	99.2	94.2
250	60	2.5	280	4.8	99.5	94.7
250	80	2.3	230	4.1	99.9	95.8
250	100	2.8	230	4.2	100.5	96.3
250	120	3	200	4.7	100.9	96.2
250	140	2.9	210	4.8	101.2	96.4
250	160	3.3	230	5.3	101.4	96.1
250	180	4.5	360	6	101.7	95.7
250	200	3	230	5	102.1	97.1
275	0	2.5	245	3.7	100.2	96.5
275	20	11.7	96	4.8	98.8	94
275	40	2.7	650	3.4	99.5	96.1
275	60	2	230	3.3	99.8	96.5
275	80	3	180	5.5	100.1	94.6
275	100	4	130	4.6	101	96.4
275	120	3.5	200	6	101	95
275	140	3.5	230	5	101	96
275	160	3	235	4.2	101.6	97.4
275	180	3.4	230	4.7	101.9	97.2
275	200	3.8	230	5.2	102.5	97.3
300	0	2.2	230	3.2	100	96.8
300	20	2.2	230	3.6	100.6	97
300	40	2.2	205	4.8	99.7	94.9
300	60	2.1	215	4.5	99.9	95.4
300	80	2.3	203	4.7	100.5	95.8
300	100	2.8	190	5	101.1	96.1
300	120	3	200	5.2	100.9	95.7
300	140	4	225	5.5	101.2	95.7
300	160	2.7	300	5.2	101.8	96.6
300	180	4.5	240	7.5	102.5	95
300	200	4.7	170	8	103.1	95.1
325	0	1.5	190	2.5	100	97.5
325	20	1.6	190	3.1	99.2	96.1
325	40	2.3	150	5	100	95
325	60	3	290	4.9	99.9	95
325	80	2	170	4.5	100	95.5
325	100	3	200	5.5	100.9	95.4
325	120	3.5	235	5.5	101.1	95.6
325	140	3	185	4.7	101.2	96.5
325	160	3.6	237	5.2	101.9	96.7
325	180	4	200	5.5	102.7	97.2
325	200	4	200	5.6	103.3	95.7

TABLE 10.9 (continued)

Station (m)	Offset Left-m	Layer 2 Depth (m)	Layer 2 Cond.	Layer 3 Depth (m)	Surface Elev. (m)	Layer 3 Elev. (m)
350	0	2	190	4.2	99.2	95
350	20	2	220	4.9	99.2	94.3
350	40	2.2	180	4.9	99.9	95
350	60	2.6	230	4.7	100.1	95.4
350	80	2.6	240	5	100.1	95.1
350	100	2.7	260	5.2	100.8	95.6
350	120	3	250	5.2	100.9	95.7
350	140	2.5	240	5.5	102.1	96.6
350	160	2.8	230	5.2	102	96.8
350	180	5	210	8	103.1	95.1
350	200	6	200	8	103.6	95.6
375	0	1.6	165	4.2	99.2	95
375	20	1.7	200	3.5	99.2	95.7
375	40	1.9	230	3.3	100.1	96.8
375	60	2.7	230	4.7	99.9	95.2
375	80	2	130	5.5	99.9	94.4
375	100	2.3	160	4.5	100.8	96.3
375	120	2.5	150	5.5	101	95.5
375	140	3	170	4.5	101.8	97.3
375	160	3.5	150	5.2	102.6	97.4
375	180	4	140	7	103.4	96.4
375	200	5	140	7	103.9	96.9
400	0	1.3	300	2.8	99.5	96.7
400	20	1.5	280	3.5	99.2	95.7
400	40	3.5	240	7	100	93
400	60	3	230	4.9	100.5	95.6
400	80	2.5	130	5.5	101	95.5
400	100	4	170	9	101.2	92.2
400	120	4.5	220	7.8	101.8	94
400	140	5.2	240	8	102.5	94.5
400	160	5	170	7.8	103.2	95.4
400	180	4	140	6.3	103.6	97.3
400	200	5.2	140	7.8	104	96.2
425	0	1.7	150	4.5	99.5	95
425	20	1.2	360	3	99.2	96.2
425	40	1.7	230	3.3	99.3	96
425	60	2.9	230	4.5	99.9	95.4
425	80	2.7	120	6.3	100.9	94.6
425	100	3	100	6.2	101.5	95.3
425	120	4	120	8	102.1	94.1
425	140	5	165	7.8	102.8	95
425	160	4.8	170	7.8	103.4	95.6
425	180	5	130	8	103.8	95.8
425	200	5	115	7.8	103.8	96

TABLE 10.9 (continued)

Station (m)	Offset Left-m	Layer 2 Depth (m)	Layer 2 Cond.	Layer 3 Depth (m)	Surface Elev. (m)	Layer 3 Elev. (m)
450	0	1.6	320	2.8	98.2	95.4
450	20	1.9	180	4.5	99.3	94.8
450	40	2.5	137	5.5	100.1	94.6
450	60	2.4	160	4.5	100.5	96
450	80	3.7	316	5	101	96
450	100	2.9	130	5.4	101.5	96.1
450	120	3.6	130	6.5	102.9	96.4
450	140	3.6	170	5.7	103	97.3
450	160	3.8	100	6.5	103.5	97
450	180	5	140	7.6	103.9	96.3
450	200	4.5	90	7.2	104.5	97.3
475	0	2.8	170	6	99.2	93.2
475	20	1	360	2.5	99.3	96.8
475	40	2.4	190	5.3	99.2	93.9
475	60	2.5	160	5.5	100.7	95.2
475	80	3.1	220	5	101.3	96.3
475	100	3.4	230	5.2	101.6	96.4
475	120	4	150	6	102	96
475	140	3.8	230	5.2	103.3	98.1
475	160	4.4	140	6.7	103.7	97
475	180	5	140	7.8	104.2	96.4
475	200	5.2	140	7.8	104.6	96.8
500	0	1.3	284	4	99.5	95.5
500	20	1.8	259	4.7	99.7	95
500	40	2.6	150	5.2	100.2	95
500	60	2.5	155	4.9	101.6	96.7
500	80	4	200	8	101.5	93.5
500	100	3	140	5.8	101.8	96
500	120	5	180	7.8	102.7	94.9
500	140	4	230	5.4	103.4	98
500	160	4.2	230	5.3	103.9	98.6
500	180	5	110	7	104.3	97.3
500	200	4.7	80	7.5	104.7	97.2
525	0	1.5	280	3.8	99.5	95.7
525	20	1.2	280	2.3	99.9	97.6
525	40	3.5	220	5	100	95
525	60	3	165	6	101.2	95.2
525	80	3.5	170	5.2	101.6	96.4
525	100	4	210	6.3	101.9	95.6
525	120	5	300	6.5	102.7	96.2
525	140	6	350	7	103.4	96.4
525	160	5	240	6.5	104	97.5
525	180	5	115	7.8	104.4	96.6
525	200	5.2	115	7.9	103.9	96

TABLE 10.9 (continued)

Station (m)	Offset Left-m	Layer 2 Depth (m)	Layer 2 Cond.	Layer 3 Depth (m)	Surface Elev. (m)	Layer 3 Elev. (m)
550	0	2	225	4.5	99.6	95.1
550	20	2.7	230	4.6	100	95.4
550	40	2.7	230	4.8	100.8	96
550	60	3	120	8	101.3	93.3
550	80	3	120	7.5	101.7	94.2
550	100	4	178	7.8	102	94.2
550	120	3.9	230	6	102.8	96.8
550	140	4.2	130	7	102.3	95.3
550	160	4.5	100	7.8	102.8	95
550	180	4.5	100	7.7	104.3	96.6
550	200	5	115	8.2	104.8	96.6
575	0	3.8	206	7.5	99.9	92.4
575	20	2.2	133	6.5	99.8	93.3
575	40	3	171	5.7	100.5	94.8
575	60	3	96	6.5	101.2	94.7
575	80	3	105	6.5	101.7	95.2
575	100	3.3	190	6	102.2	96.2
575	120	3.4	125	6.5	102.8	96.3
575	140	5	190	7.6	103.2	95.6
575	160	5	150	8	103.5	95.5
575	180	4.2	106	8	104	96
575	200	4.8	130	7.8	104.7	96.9
600	-120	2.4	230	5.1	99.2	94.1
600	-100	2.2	230	5	99.2	94.2
600	-80	3.6	200	8	99.2	91.2
600	-60	2	372	4	99.2	95.2
600	-40	4	310	7.5	99.5	92
600	-20	4	238	7	100	93
600	0	4.3	209	6.5	100.2	93.7
600	20	3.6	191	6	100	94
600	40	2.3	90	6	101	95
600	60	3.5	125	8	101.4	93.4
600	80	3.5	160	6	101.7	95.7
600	100	3.5	150	7.8	102	94.2
600	120	3.5	186	6	102.5	96.5
600	140	4.5	170	9	103	94
600	160	5	115	9	103.4	94.4
600	180	5	106	9	103.8	94.8
600	200	6.4	124	10.5	104.1	93.6
625	-120	1.8	218	5.5	99.2	93.7
625	-100	1.3	230	3.5	99.2	95.7
625	-80	2.6	215	6.5	99.2	92.7
625	-60	21	220	6	99.2	93.2
625	-40	1.7	202	4.5	98.8	94.3

TABLE 10.9 (continued)

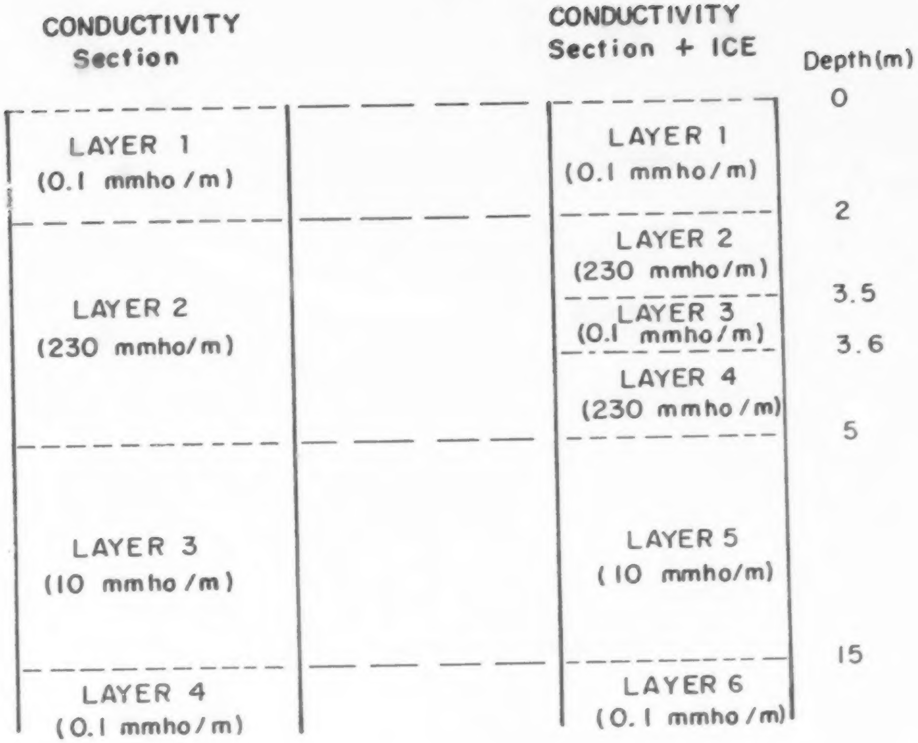
Station (m)	Offset Left-m	Layer 2 Depth (m)	Layer 2 Cond.	Layer 3 Depth (m)	Surface Elev. (m)	Layer 3 Elev. (m)
625	-20	3	170	7.2	99.5	92.3
625	0	3	155	7.8	99.9	92.1
625	20	3	150	6.2	100.3	94.1
625	40	6	300	8	100.9	92.9
625	60	4	220	6.3	101.3	95
625	80	4.5	140	8	101.6	93.6
625	100	5	170	8	102	94
625	120	3.5	142	6.5	102.6	96.1
625	140	3.3	121	7	103	96
625	160	3.7	146	6	103.2	97.2
625	180	4.2	110	7.8	103.7	95.9
625	200	4.8	100	9	103.9	94.9
650	-120	2.9	455	4.7	99.2	94.5
650	-100	2.3	230	5.3	99.2	93.9
650	-80	2.1	230	5.1	99.2	94.1
650	-60	2.5	190	6	99.2	93.2
650	-40	1.9	210	4.5	99.2	94.7
650	-20	1.5	190	5	99.2	94.2
650	0	2.7	180	6.8	99.9	93.1
650	20	1.8	100	7	100.1	93.1
650	40	3.5	117	6.8	100.5	93.7
650	60	2.5	160	7	100.8	93.8
650	80	2.8	130	6.5	101.2	94.7
650	100	3.4	165	5.8	102	96.2
650	120	4	90	7.3	102.6	95.3
650	140	4.1	133	7.2	103.1	95.9
650	160	3.4	100	7.5	103.2	95.7
650	180	4	160	7	103.5	96.5
650	200	4.5	150	7.5	103.8	96.3
675	-120	1.7	230	5	99.2	94.2
675	-100	1.8	360	4.3	99.2	94.9
675	-80	1.9	370	4	99.2	95.2
675	-60	2	360	4	99.2	95.2
675	-40	1.2	220	5	99.2	94.2
675	-20	1.5	200	5.5	99.5	94
675	0	2.7	200	6	100	94
675	20	2.3	170	5	100	95
675	40	1.8	200	4.7	101.4	96.7
675	60	3.1	153	6	100.7	94.7
675	80	3.5	150	7	101	94
675	100	3.7	135	6.2	101.64	95.44
675	120	2.9	130	5.4	102.1	96.7
675	140	4	115	7.5	102.7	95.2
675	160	3.6	140	6	102.9	96.9

TABLE 10.9 (continued)

Station (m)	Offset Left-m	Layer 2 Depth (m)	Layer 2 Cond.	Layer 3 Depth (m)	Surface Elev. (m)	Layer 3 Elev. (m)
675	180	5	240	7	103.2	96.2
675	200	5.5	240	8	103.5	95.5
700	-120	2.4	440	4.4	99.2	94.8
700	-100	1.8	410	4.4	99.2	94.8
700	-80	1.9	400	4.4	99.8	95.4
700	-60	1.7	350	3.5	99.2	96.7
700	-40	2	250	4.2	99.2	95
700	-20	3.2	270	7	99.7	92.7
700	0	2.8	220	5.9	99.5	93.6
700	10	3.5	220	7.5	99.9	92.4
700	30	2.8	170	6.8	100.3	93.5
700	50	3	165	5.9	100.9	95
700	70	3	160	5.3	101.1	95.8
700	90	2.5	130	5	101.5	96.5
700	110	3	140	5.5	101.8	96.3
700	130	3.8	160	6	102.2	96.2
700	150	4	150	6.3	102.5	96.2
700	170	5	200	7	102.8	95.8
700	180	5	190	7.3	103	95.7
700	200	5.2	190	7.5	103.3	95.8
725	-120	2.7	420	4.5	99.2	94.7
725	-100	1.5	250	6.3	99.2	92.9
725	-80	1.5	230	4.3	99.2	94.9
725	-60	2.6	200	6	99.3	93.3
725	-40	2.7	230	6.5	99.4	92.9
725	-20	2.8	240	5.5	99.4	93.9
725	0	3	200	7	99.8	92.8
725	20	2.5	170	5.7	100	94.3
725	40	2.5	180	5.5	100.6	95.1
725	60	4.3	300	6	101.1	95.1
725	80	2	122	5.5	101.4	95.9
725	100	3	150	6	101.6	95.6
725	120	3.4	200	5.5	101.8	96.8
725	140	4.8	250	6.9	102.2	95.3
725	160	3.5	150	6.4	102.4	96
725	180	3.7	140	7	102.6	95.6
725	200	5	200	8	103	95
750	-120	1.9	440	4.3	99.2	94.9
750	-100	2	440	4	99.2	95.2
750	-80	2.8	240	6.5	99.2	92.7
750	-60	2.7	222	6.4	99.2	92.8
750	-40	2.7	185	6.7	99.7	93
750	-20	2.9	230	6.3	103.2	96.9
750	0	2.6	230	5.1	100	94.9

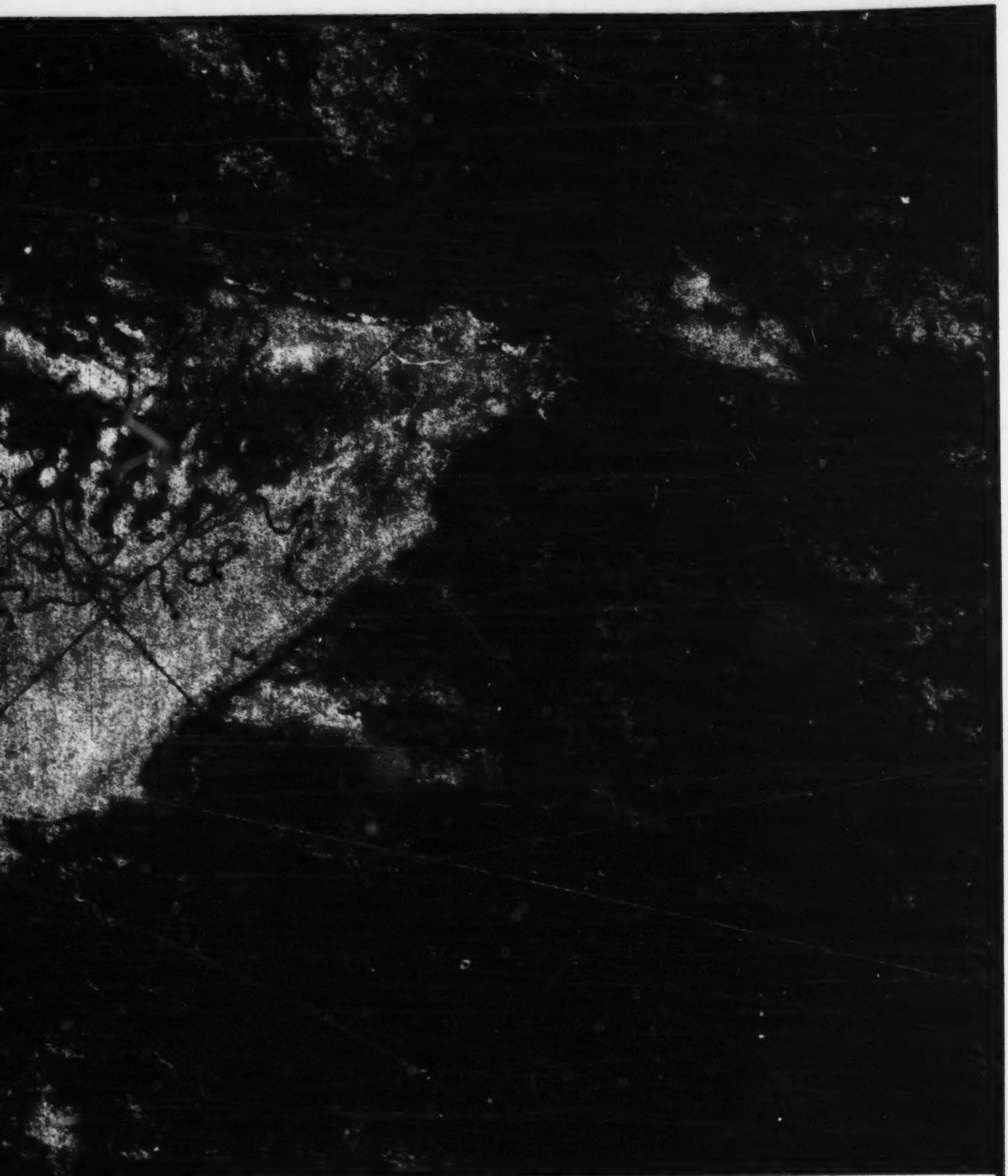
TABLE 10.9 (continued)

Station (m)	Offset Left-m	Layer 2 Depth (m)	Layer 2 Cond.	Layer 3 Depth (m)	Surface Elev. (m)	Layer 3 Elev. (m)
750	20	2.6	200	5.7	100.4	94.7
750	40	3	175	6.5	100.9	94.4
750	60	2.4	200	6	101.1	95.1
750	80	2.6	230	4.8	101.3	96.5
750	100	2.7	230	4.9	101.6	96.7
750	120	3.9	130	6.5	101.7	95.2
750	140	4	140	9	101.8	92.8
750	160	4.3	155	7.5	102	94.5
750	180	3.2	120	7	102.2	95.2
750	200	3.7	140	7.5	102.7	95.2
775	-120	2	430	4	99.2	95.2
775	-100	1.4	360	4.1	99.2	95.1
775	-80	2.1	230	5.4	99.2	93.8
775	-60	2.5	190	5.8	99.2	93.4
775	-40	2.5	200	5	99.8	94.8
775	-20	2.3	190	5	99.8	94.8
775	0	2.8	200	6.5	100	93.5
775	20	2.2	200	5.5	100.6	95.1
775	40	2.6	150	7.5	101	93.5
775	60	2.6	210	6.5	101.3	94.8
775	80	2	230	4.3	101.5	97.2
775	100	2.8	165	7	101.7	94.7
775	120	2.4	140	6.5	101.7	95.2
775	140	2.5	170	5.8	101.9	96.1
775	160	3.5	190	6.5	101.9	95.4
775	180	3.2	130	7.2	101.9	94.7
775	200	3.7	130	8	102.6	94.6
800	-120	2	320	4.3	99.2	94.9
800	-100	2	480	3.4	99.2	95.8
800	-80	2.2	200	6.9	99.2	92.3
800	-60	2.7	206	6.7	99.4	92.7
800	-40	2.7	206	6.8	99.6	92.8
800	-20	2.3	220	4.9	99.8	94.9
800	0	2.9	196	5.8	100	94.2
800	20	2.4	197	5.9	101	95.1
800	40	2.9	190	6.3	101.2	94.9
800	60	2.7	198	6.2	101.4	95.2
800	80	3	173	7	101.6	94.6
800	100	3.4	166	8	101.8	93.8
800	120	4	180	7.8	102	94.2
800	140	3.8	160	7.5	102.2	94.7
800	160	3.5	140	6.5	102.7	96.2
800	180	3.2	120	7	103.1	96.1
800	200	2.5	110	4.2	103.3	99.1


CONDUCTIVITY
Section
CONDUCTIVITY
Section + ICE
Depth(m)
0
2
3.5
3.6
5
15
LAYER 1
(0.1 mmho/m)
LAYER 2
(230 mmho/m)
LAYER 3
(10 mmho/m)
LAYER 4
(0.1 mmho/m)
LAYER 1
(0.1 mmho/m)
LAYER 2
(230 mmho/m)
LAYER 3
(0.1 mmho/m)
LAYER 4
(230 mmho/m)
LAYER 5
(10 mmho/m)
LAYER 6
(0.1 mmho/m)

	THEORETICAL RESPONSE		CHANGE %
50.2 mmho/m	EM31 (hor.)	48.0 mmho/m	-4
78.7 "	EM31 (vert.)	76.3 "	-3
63.0 "	EM34-10 (hor.)	61.1 "	-3
54.9 "	EM34-10 (vert.)	53.1 "	-3
23.3 "	EM34-20 (vert.)	22.6 "	-3

Figure 10.14: Effect of Adding an Ice Lens into Conductivity Section



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THICKNESS OF LAYER 1

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SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1:5000
DATE DEC. '85
DRAWN BY W.T.
APPROVED BY

FIGURE 10.15

>400 mmho/m
141-200 mmho/m
283-400 mmho/m
100-141 mmho/m
200-283 mmho/m
< 100 mmho/m
NOTE : LOGRITHMIC CONTOUR INTERVAL

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CONDUCTIVITY OF LAYER 2

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SCALE 1: 5000
DATE DEC. '85
DRAWN BY W.T.
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FIGURE 10.16

10.5.5.3 Conductivity of Layer 2 (Figure No. 10.16)

The conductivity of zones shown on Figure No. 10.16 are at a logarithmic interval. The values are within 10-20 percent of the true conductivity of Layer 2.

The conductivity tends to be lower in the southeast part of the area, where Layer 1 is thickest. The highest conductivity zone is northwest of the baseline (where stations are labelled as negative), in an area where the water ponds on surface. Smaller local areas of high conductivity are below thicker zones of Layer 1 at the mounded tailings (see Section 10.5.7).

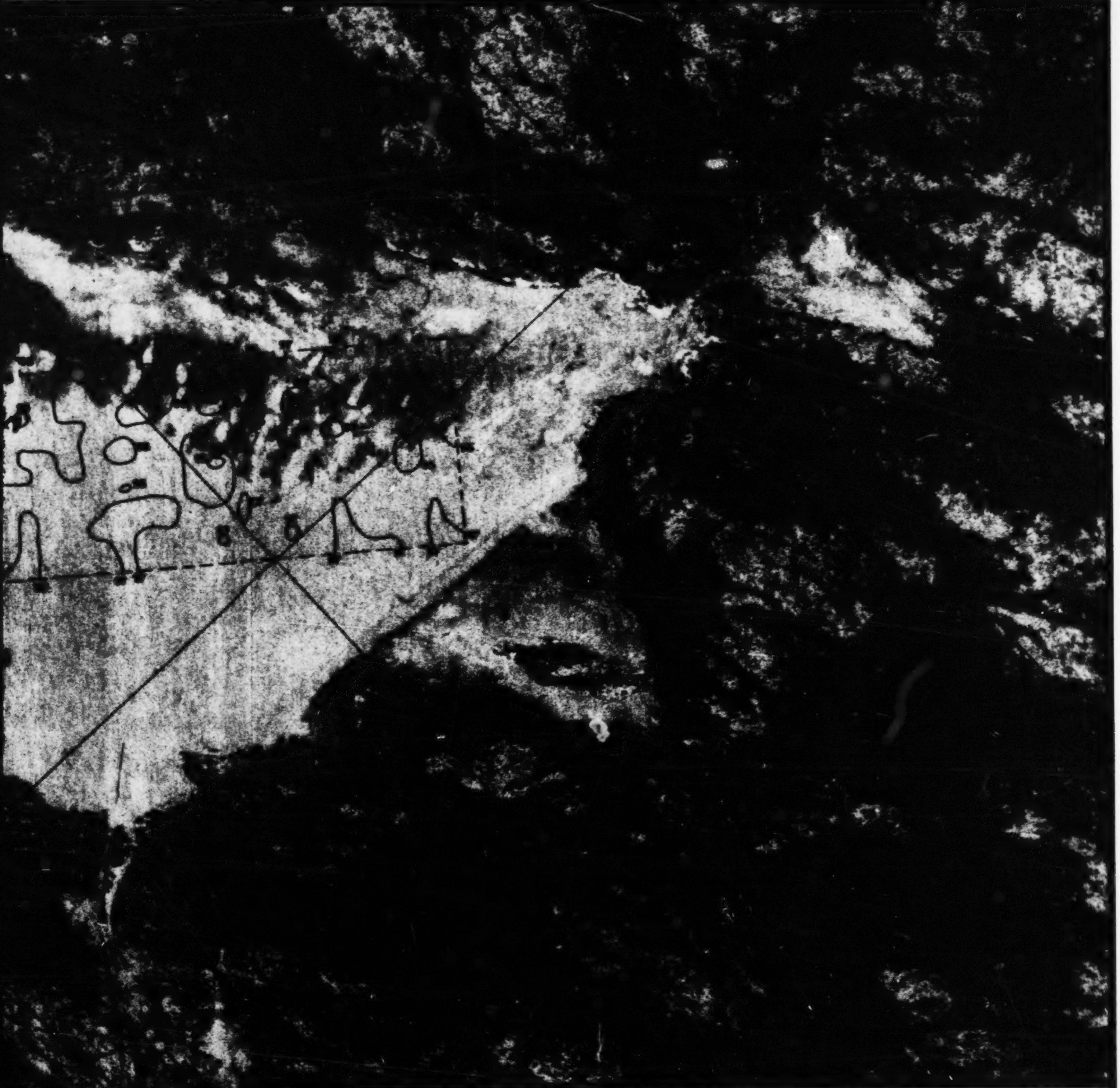
10.5.5.4 Elevation of the Top of Layer 3 (Figure No. 10.17)

The accuracy of the values presented is subject to errors in the interpolation of surface elevation from the topographic map of the site and the effects of varying snow cover. As a result, the reported elevation has an error of up to 2-3 m (15-25 percent of the depth of the layer).

The elevation is fairly constant over most of the site, decreasing slightly to the east. The small local anomalies and the depressions corresponding to areas of mounded tailings ("A" for example) are probably a function of the interpretation and are unlikely to be real.

10.5.5.5 Bedrock Surface (Figure No. 10.18)

The accuracy of resolving layers below the highly conductive tailings is much lower than for those above. Referring again to Table 10.8, errors in "depth to" and "conductivity" of Layer 3 control the EM34-20 vertical reading far more than does variations in the depth to bedrock. Therefore, it would be misleading to assume the calculated values for the bedrock elevation as absolute. The plots presented should be taken as reflecting relative changes in bedrock, as shallow or deep, rather than actual numerical values.



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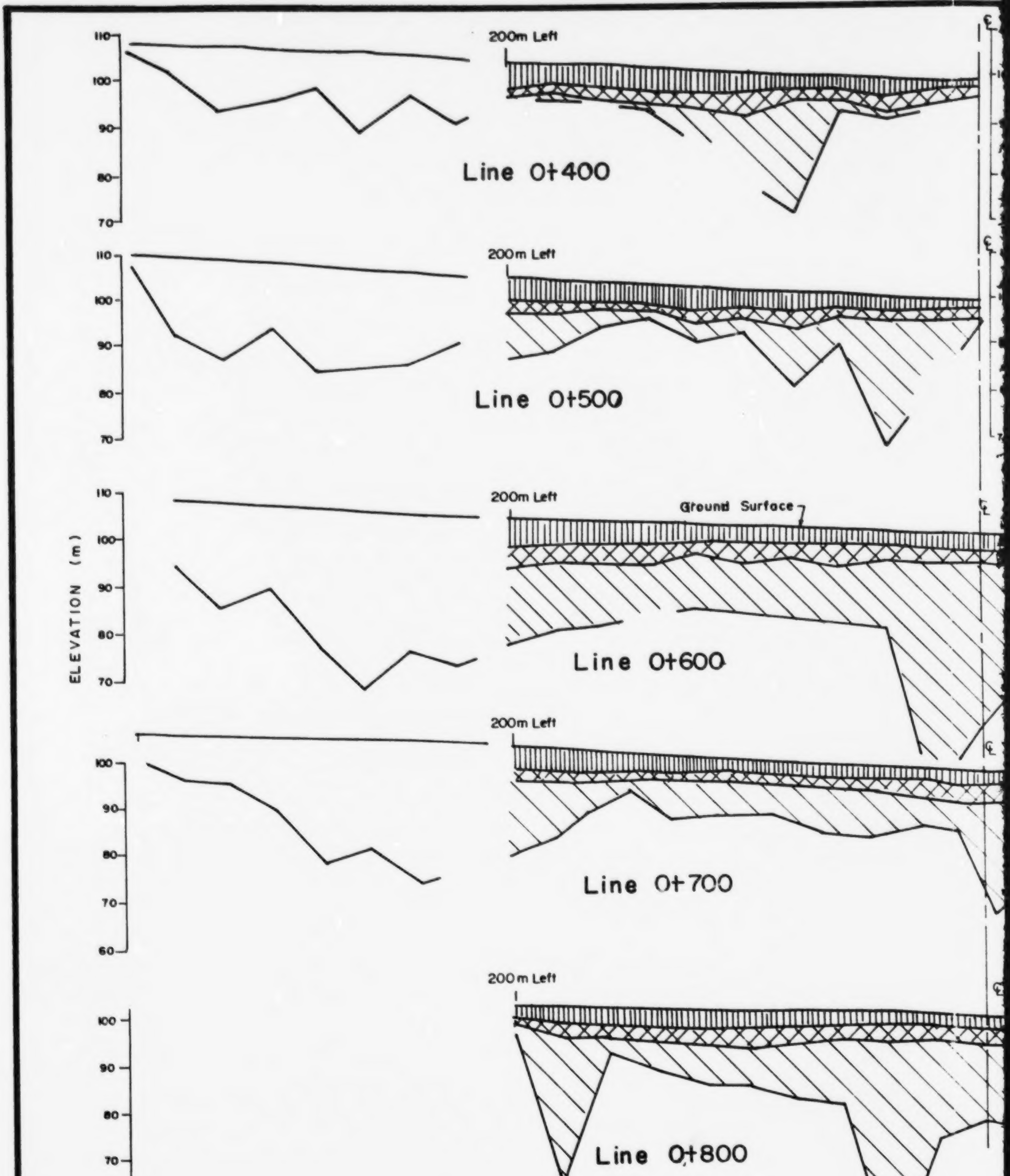
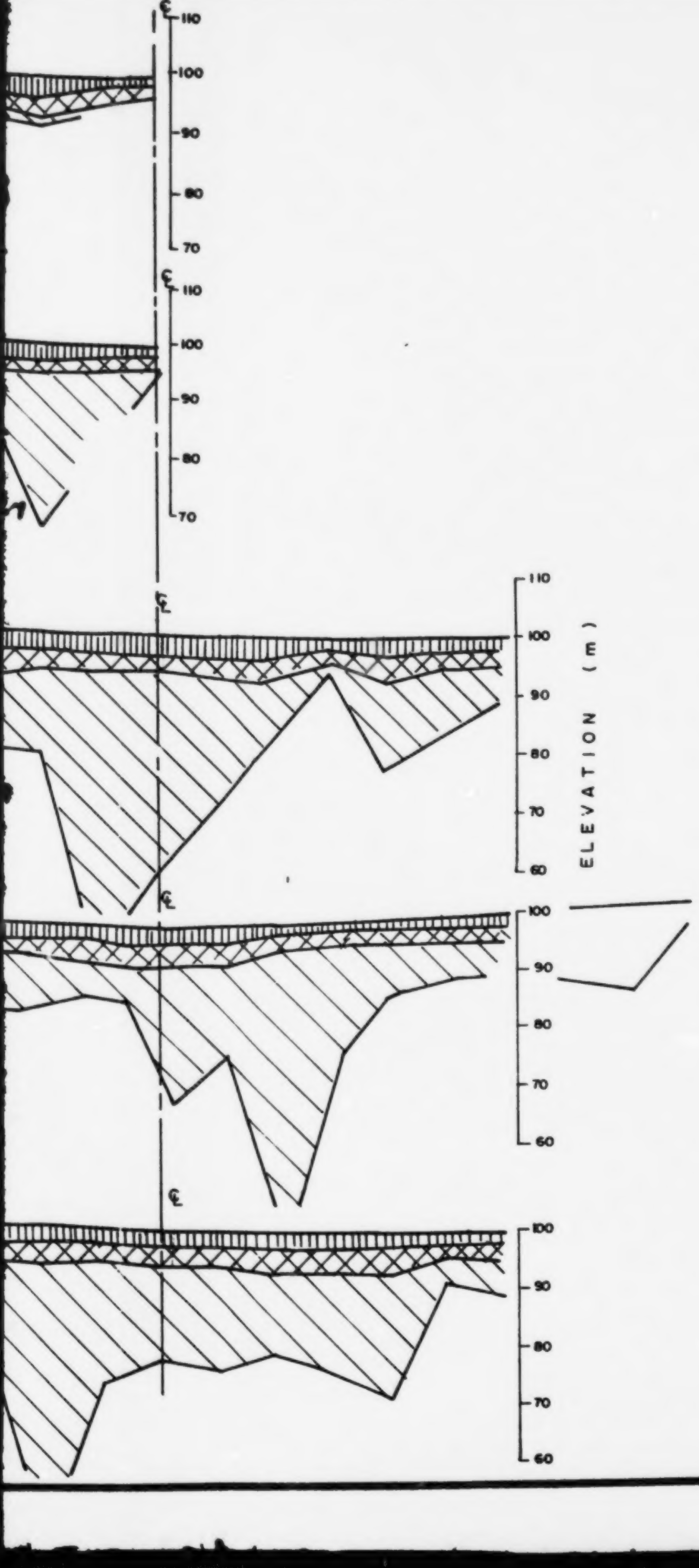
Elevation of Top of Layer 3

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1: 5000
DATE DEC. '85
DRAWN BY W. T.
APPROVED BY

FIGURE 10.17


ELEVATION (m)
110
100
90
80
70
60
200m Left
Ground Surface
Line 0+400
Line 0+500
Line 0+600
Line 0+700
Line 0+800


℄
110
100
90
80
70
℄
110
100
90
80
70
℄
110
100
90
80
70
60
ELEVATION (m)
℄
100
90
80
70
60
℄
100
90
80
70
60

LEGEND:

▥ LAYER 1 ▩ LAYER 2 ▨ LAYER 3

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BEDROCK SURFACE

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GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE: H 1:2000 V 1:1000	DATE JAN. 1986	FIGURE 10.18
DRAWN BY: W.T.	APPROVED BY	

The bedrock surface rises to the north. From line 400 north, the bedrock is so shallow that any errors in the interpretation overshadow the influence of Layer 3. In the southern part of the grid, 2 bedrock knolls or highs occur at line 600, station 60 left and line 800, station 200 left.

Each of the lines has 2 zones of very deep bedrock. When these anomalies are connected between lines, they fall along 2 linear trends (shown on Figure No. 10.18). The size of the calculated anomalies indicates that bedrock elevation may not be the only controlling factor. There also may be zones of anomalously high bedrock conductivity, possibly due to either faulting or an intrusion.

10.5.5.6 Langley Bay

The results of the survey at Langley Bay are shown as a cross-section on Figure No. 10.19. The same restrictions and qualifications on the interpretation that were discussed for the Gunnar Main site apply here as well.

The results of the geophysical survey compare to borehole data available within the error limits presented.

10.5.6 Summary

Based on the EM survey, the Gunnar Main Tailings impoundment is considered to be a 4 layer case. The top layer combines everything above the water table, i.e. surface snow, frozen tailings and any unsaturated tailings. The layer ranges in thickness from 2 m in the east to 5 m along the west part of the site, roughly reflecting surface topography.

The underlying layer is saturated tailings. The conductivity of the second layer varies from approximately 130 mmhos/m along the west, at its deepest, to 400 mmhos/m in the east where water ponds on surface.

The third layer, a silty clay, has a fairly flat surface, deepening slightly to the east.

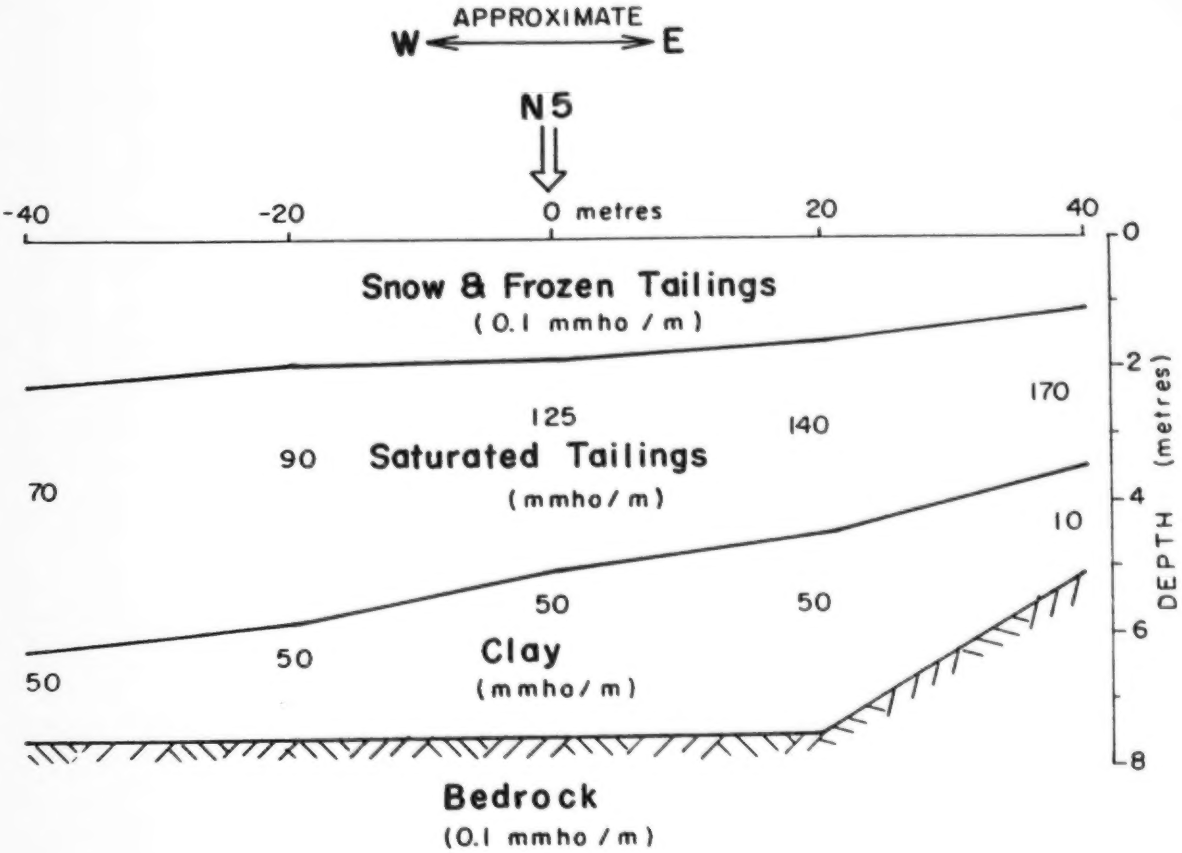

APPROXIMATE
W
E
N5
-40
-20
0 metres
20
40
0
2
4
6
8
DEPTH (metres)
Snow & Frozen Tailings
(0.1 mmho / m)
170
125
140
90
Saturated Tailings
70
(mmho/m)
10
50
50
Clay
50
50
(mmho/m)
Bedrock
(0.1 mmho / m)

Figure 10.19 LANGLEY BAY
Cross Section

This sequence is underlain by bedrock. The bedrock surface is shallow in the northern part of the site. Two linear anomalies, one east/west and the other northwest/southeast occur in the bedrock. These are probably of comparatively high conductivity and deeper bedrock.

On the tailings surface, a number of "mounds" exist. At these locations, Layer 1 tends to be locally thicker and the saturated tailings are more conductive than the surrounding area.

The primary objective of the survey, the location and extent of thin ice lenses could not be interpreted from the data due to the extremely high conductivity of the tailings.

10.5.7 Potential Information From Future Geophysics on the Site

Any surficial geophysical technique that measures conductance (or resistance) will have its response dominated by the high conductivity tailings. Layering above the tailings would be resolvable. For instance, if variations in the depth to the water table, or progression of surface freezing is of interest, electrical techniques would work. As reported, variations in the conductivity of the tailings can also be resolved. However, thin layers of ice are unlikely to be picked up by any surface electrical technique.

Of the available electrical techniques, the EM instruments are likely to be the best choice. Conventional resistivity is too slow. Radar techniques would yield excellent resolution above the tailings, but give no information of lateral conductivity variations in the tailings and are expensive to use.

Seismic refraction has the best chance of picking up any ice lenses if they are continuous, but the technique can only be used when the surface is not frozen.

A downhole alternative to surface techniques for measuring the progression of surface freezing and variations in conductivity is the Disposable E-log. The device is cost effective since it also allows for water sampling. A description of the technique is given by Greenhouse et al.

Geophysical techniques are unlikely to be of much additional use as an xploratory tool at the Gunnar Main site. However, geophysics is an excellent monitoring tool for measuring changes in the stratigraphy over time.

10.6 ANALYSIS AND CONCLUSIONS

The additional test drilling confirmed the presence of permanently frozen tailings within the elevated mounds on Gunnar Main (Test Hole Nos. N2A, GM2A and GM6A). It is also significant, however, that the drilling did not encounter any permanently frozen tailings in the areas immediately adjacent to the mounds. Generally, the thermistor readings confirmed the visual observations, although in some cases (Test Hole No. N2F) the thermistor was not installed deep enough to reach the permanently frozen ground. It would seem reasonable to conclude, therefore, that the elevated mounds found on Gunnar Main are the result of permafrost.

The electromagnetic (EM) survey was inconclusive in determining areas of permafrost because of the relatively high conductivity of the saturated tailings. It was originally intended that the combined results of the additional field measurements could be used to generate some fundamental understanding of frost in tailings in the discontinuous permafrost zone of Northern Saskatchewan. Largely as a result of the ineffectiveness of the EM survey, this was not possible, however.

Some insight into the factors which might contribute to the formation of the permafrost zones in the tailings can be found by looking at some of the other data generated by The Gunnar Field Study.

1. Texture of the Tailings

   Figure No. 10.20 presents 2 bands of grain size curves prepared from the results of 21 grain size tests of tailings sampled from the test holes included in Section 10.4.1. Two materials were identified, namely, a fine silty sand with 12 to 46 percent passing the 80 um sieve and a silt with 10 to 28 percent coarser than the 80 um sieve. The most predominant tailings material was the silty sand (17 samples), with the silt (4 samples) generally encountered in the area of Test Hole Nos. GM6 and GM4.

   There was a general tendency towards siltier composition with increasing depth and in low lying areas of the tailings.

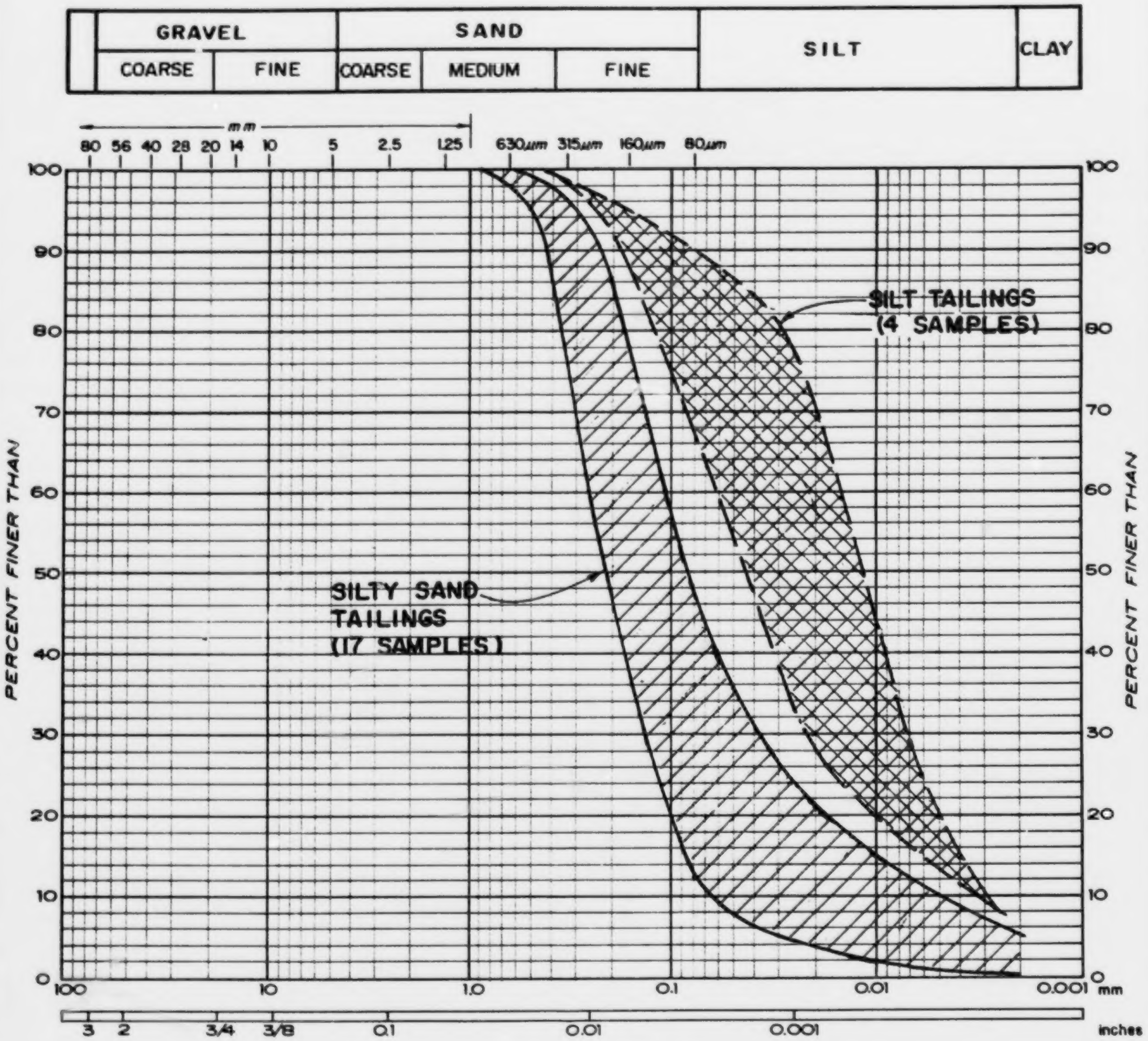
2. Permeability of the Tailings

   Both the laboratory and field permeability tests established a range of 1E-03 to 1E-06 cm/sec for the tailings at the Gunnar Mine. Both sets of data also established that the lower values of 1E-04 to 1E-06 cm/sec were related to the finer textured tailings.

3. Groundwater Table

   Table 10.10 presents the water table information for the monitor wells installed within the study area. Generally, the water table was within 3 m of the tailings surface. Figure No. 10.21 illustrates the movement of groundwater in the tailings from the topographic high to the topographic low, with water ponding on the surface in the topographic lows.

The surface mounds were primarily found in the topographic lows of the Gunnar Main Tailings. Three factors which are also common to the topographic lows are finer, siltier textured tailings, tailings with a lower permeability, and a high water table. All 3 of these factors are conducive to frost action.



REMARKS: *TYPICAL TAILINGS GRAIN SIZE DISTRIBUTION*

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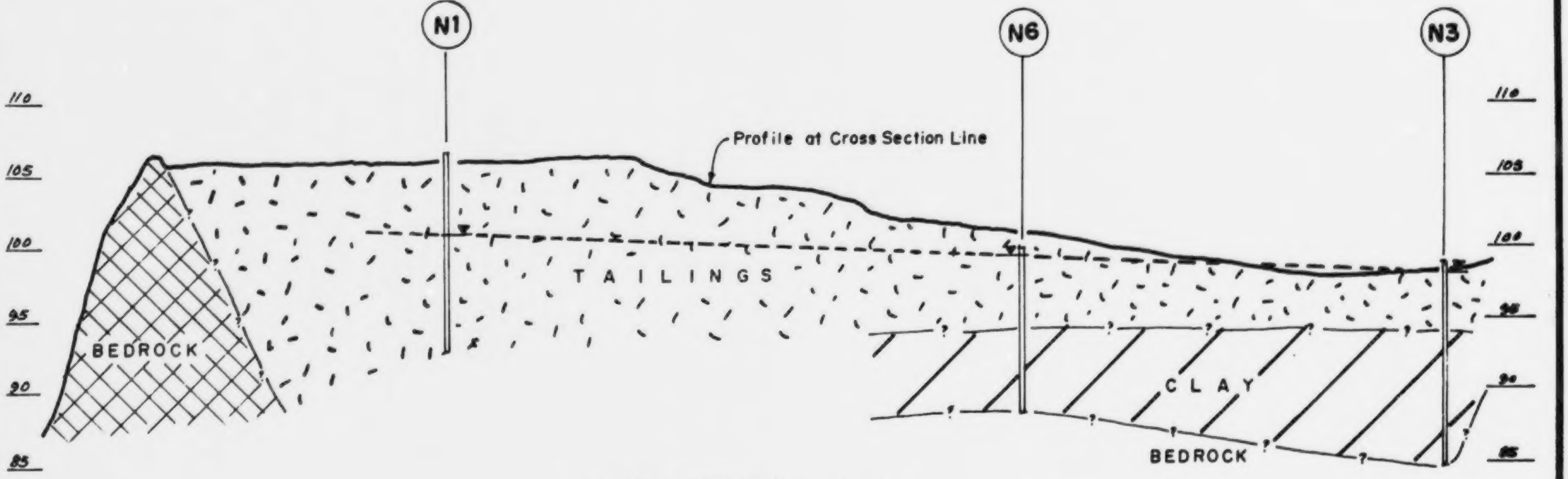
GRAIN SIZE DISTRIBUTION

FIGURE 10.20


N1
N6
N3
110
105
100
95
90
85
Profile at Cross Section Line
TAILINGS
BEDROCK
CLAY
BEDROCK

·SECTION A-A·

GUNNAR MAIN TAILINGS

0
40
80
120
160
200
240
280
HORIZONTAL SCALE (m)
LEGEND
GRAVEL
SAND
SILT
CLAY
CLAYTILL
ORGANIC
3 TEST HOLE LOCATION
PIEZOMETER TIP DEPTH
RECORDED WATER LEVEL

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INTERPRETED SUBSOIL STRATIGRAPHY

NOTE: THE INFERRED SOIL STRATIFICATION HAS BEEN INTERPRETED FROM DATA OBTAINED AT TEST HOLE LOCATIONS ONLY. THE INFERRED CONTACTS SHOWN ARE BASED ON GEOLOGICAL EVIDENCE AND MAY VARY FROM THOSE SHOWN BETWEEN TEST HOLES.

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN
FIGURE NO. 10.21

Table 10.10
Water Level Observations
August 1985 Campaign
EM Survey Area

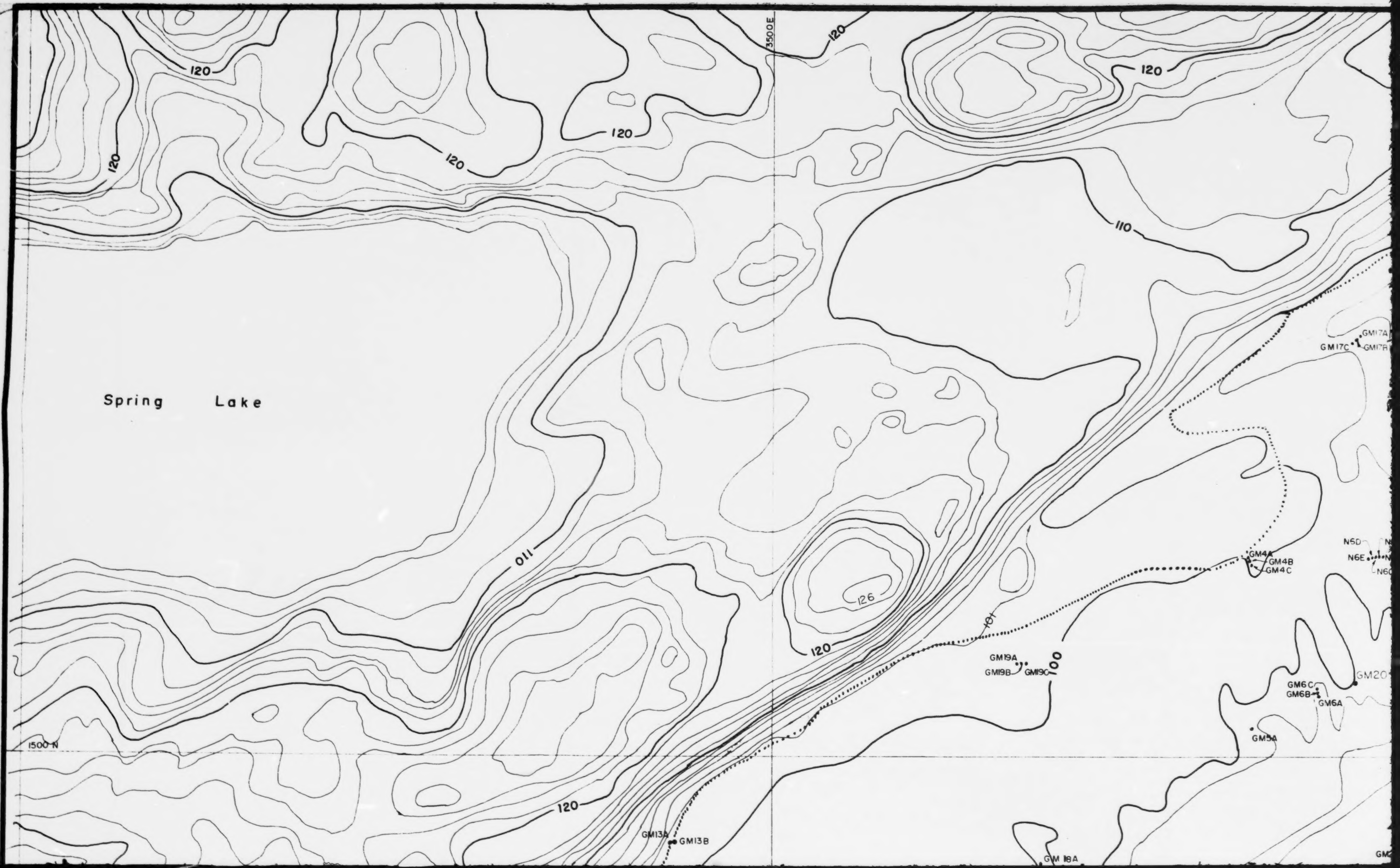
Monitor Well	Depth to Water -m-	Casing Elevation -m-	Casing Height above Surface-m	Water Below Ground Surface-m	Elevation -m-
N2C	1.54	101.94	0.15	1.60	100.10
N6D	0.99	100.42	0.53	0.46	99.43
GM2C	3.51	104.42	0.35	3.16	100.91
GM3C	1.64	102.50	0.515	1.12	100.86
GM4B	1.70	101.38	0.40	1.30	99.68
GM6B	3.22	102.10	0.42	2.80	98.88
GM9C	2.00	101.74	0.30	1.70	99.71
GM17B	1.52	100.02	0.34	1.18	98.50

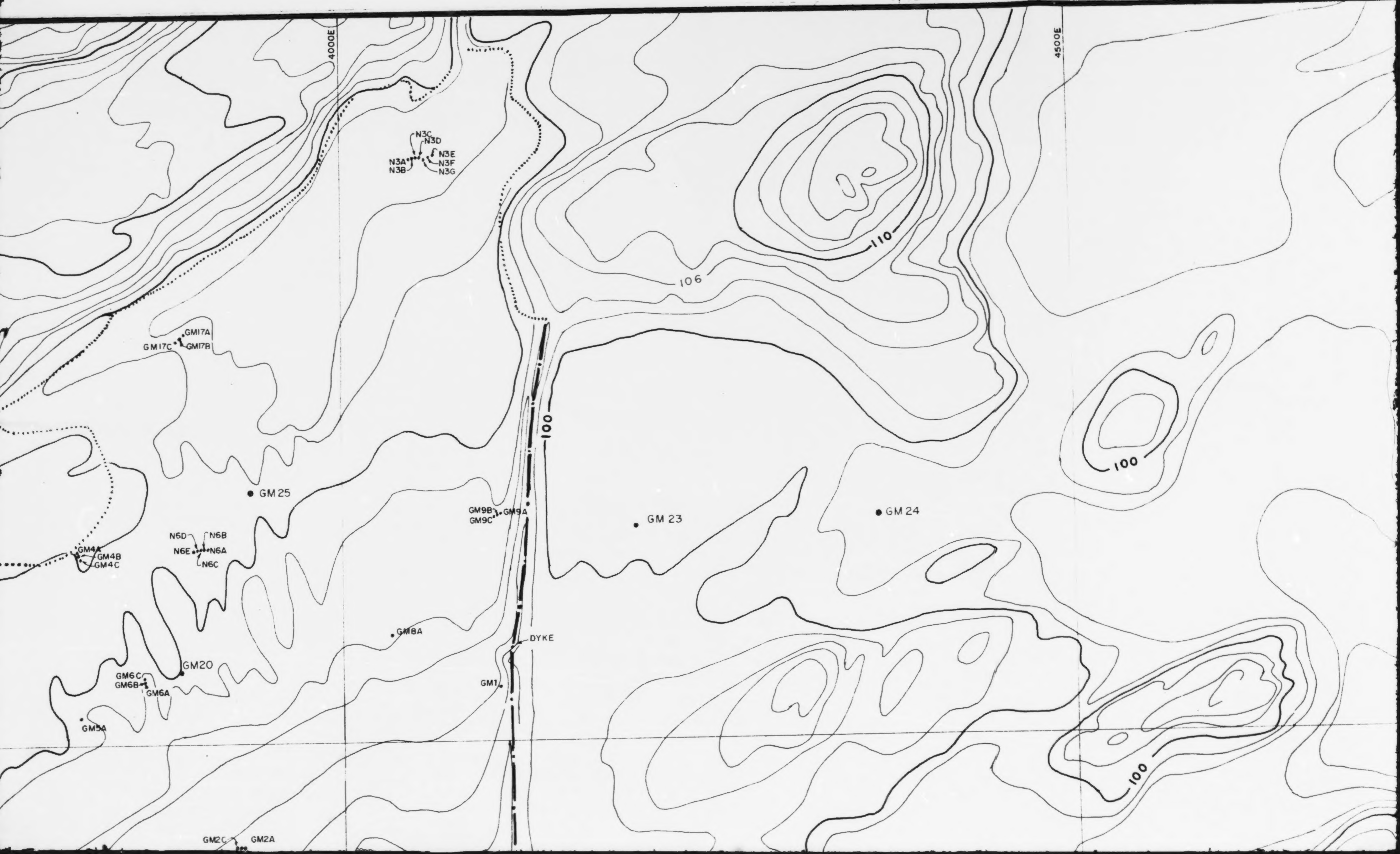
The occurrence of permanently frozen ground within the tailings at some locations suggests that this condition might be cultivated as a means of reducing release rates. The data collected as part of The Gunnar Field Study, however, were not detailed enough to provide the specific combinations of tailings type, water table position, snow cover, climate and exposure which would be necessary to develop this condition.

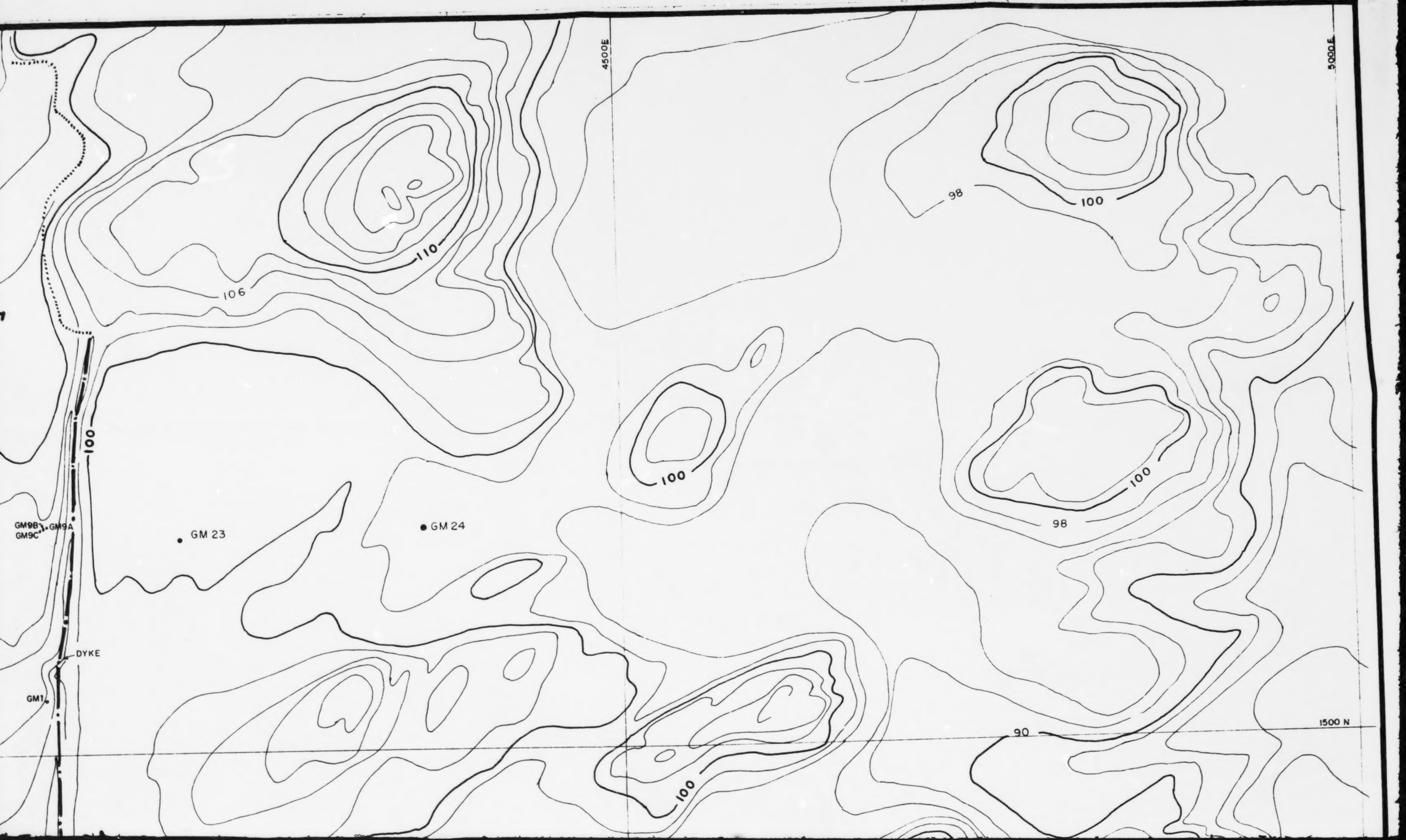
10.7 REFERENCES

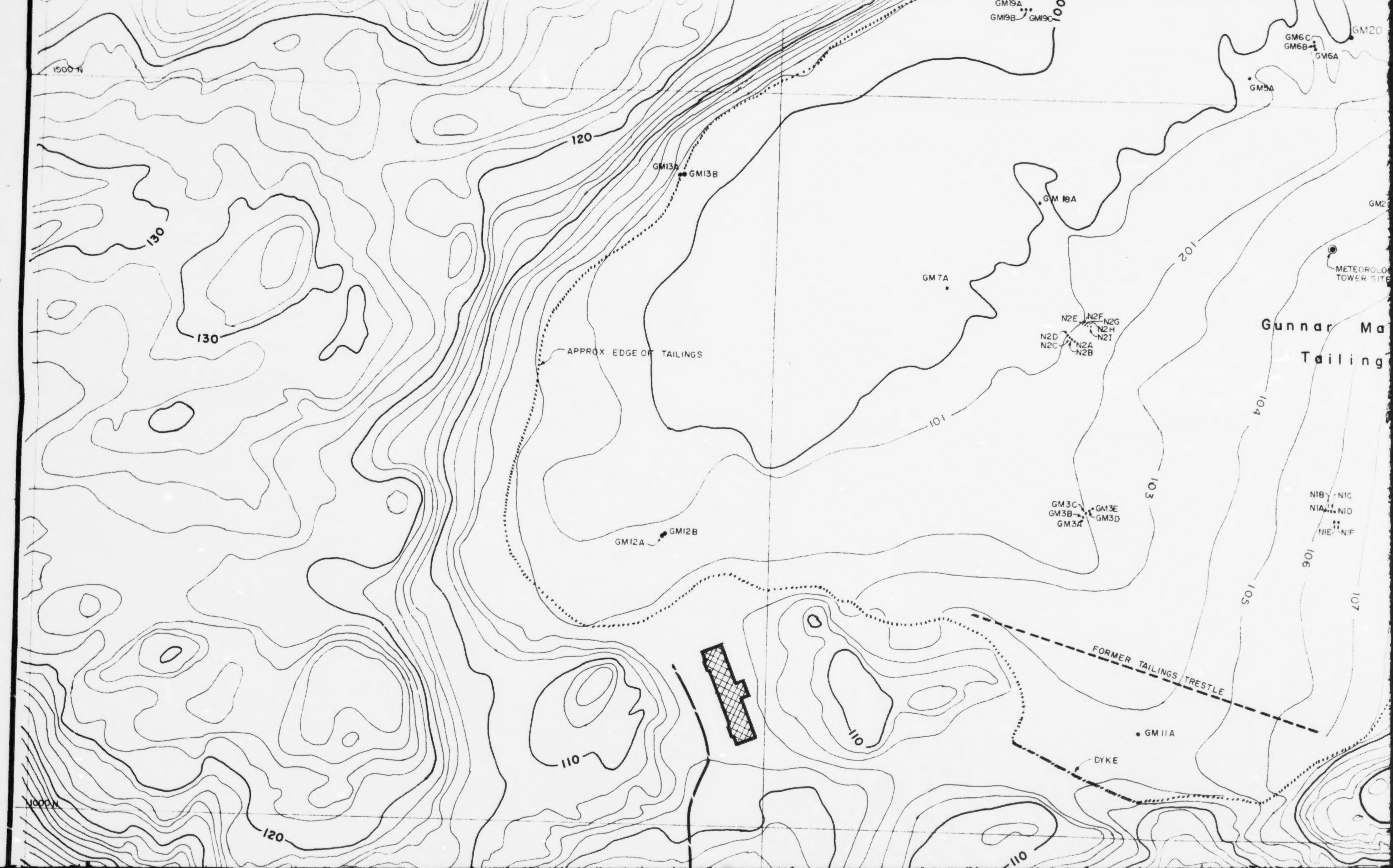
MACNEIL, J.D., 1980. Electromagnetic Terrain Conductivity Measurement at Low Induction Numbers. Technical Note TN-6 Geonics Ltd., Mississauga. Pg 15.

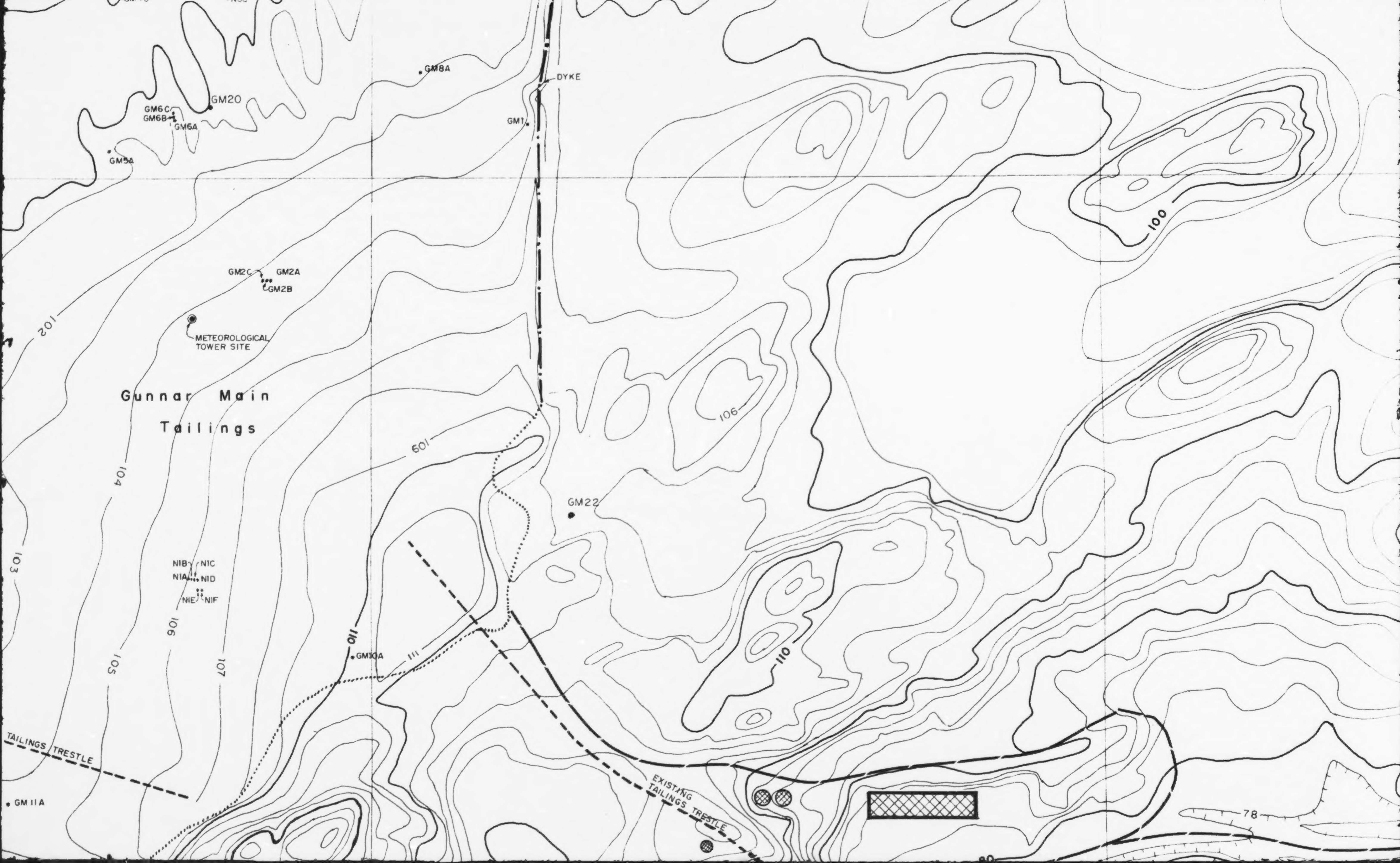
GREENHOUSE, J.P., FAULKNER, L.A., PEHME, P.E., WONG, J. 1985. Geophysical Monitoring of an Injection Contamination Plume: Experiments with a Disposable E-Log. Proceeds of 2nd National Conference on Surface and Borehole Geophysical Methods in Groundwater Investigations, NWWA. Fort Worth.

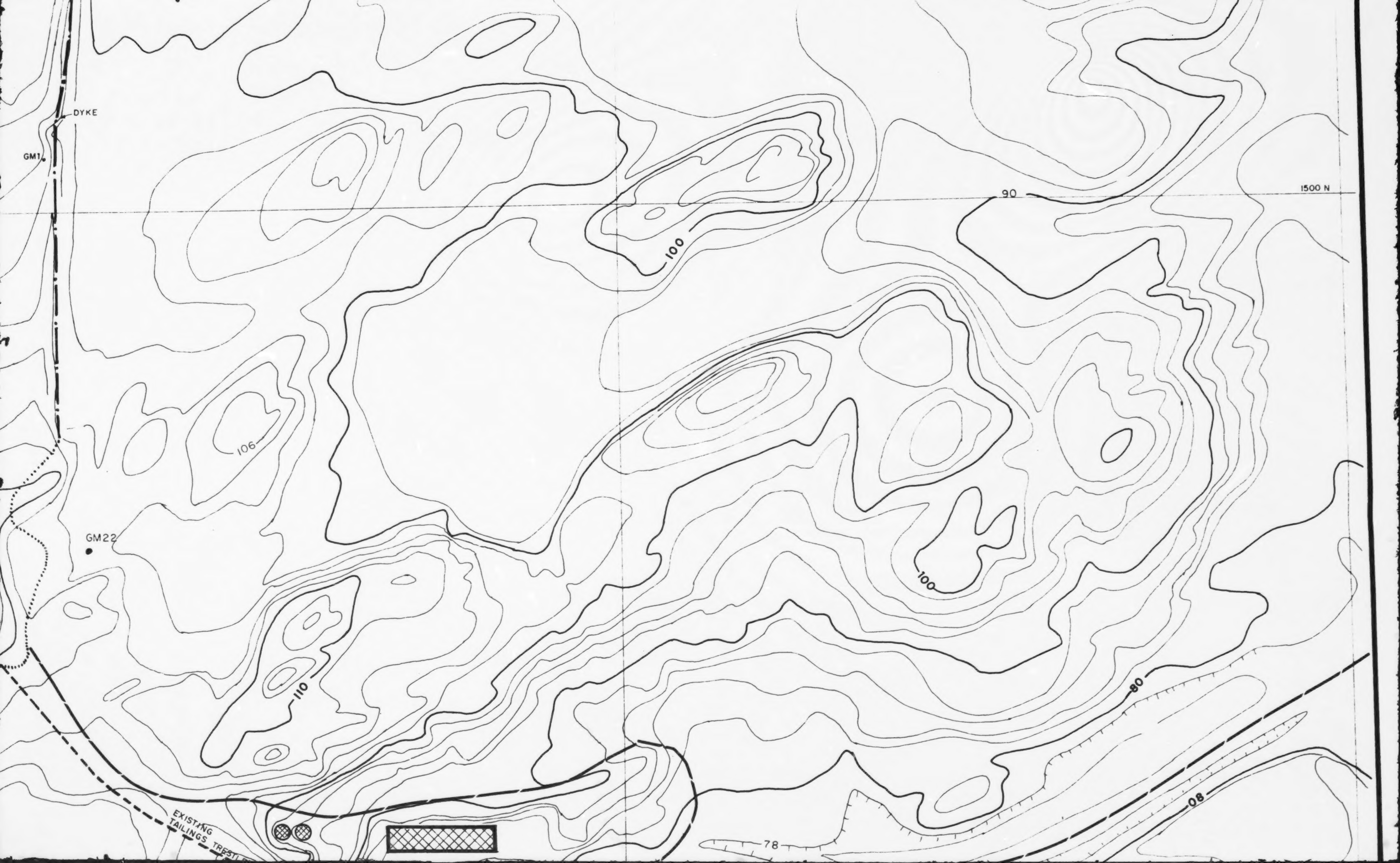

120
120
120
120
120
120
120
3500E
110
Spring Lake
110
126
120
101
100
120
1500 N
GM17A
GM17C
GM17B
GM4A
GM4B
GM4C
N5D
N6E
GM19A
GM19B
GM19C
GM20
GM6C
GM6B
GM6A
GM5A
GM13A
GM13B
GM 18A

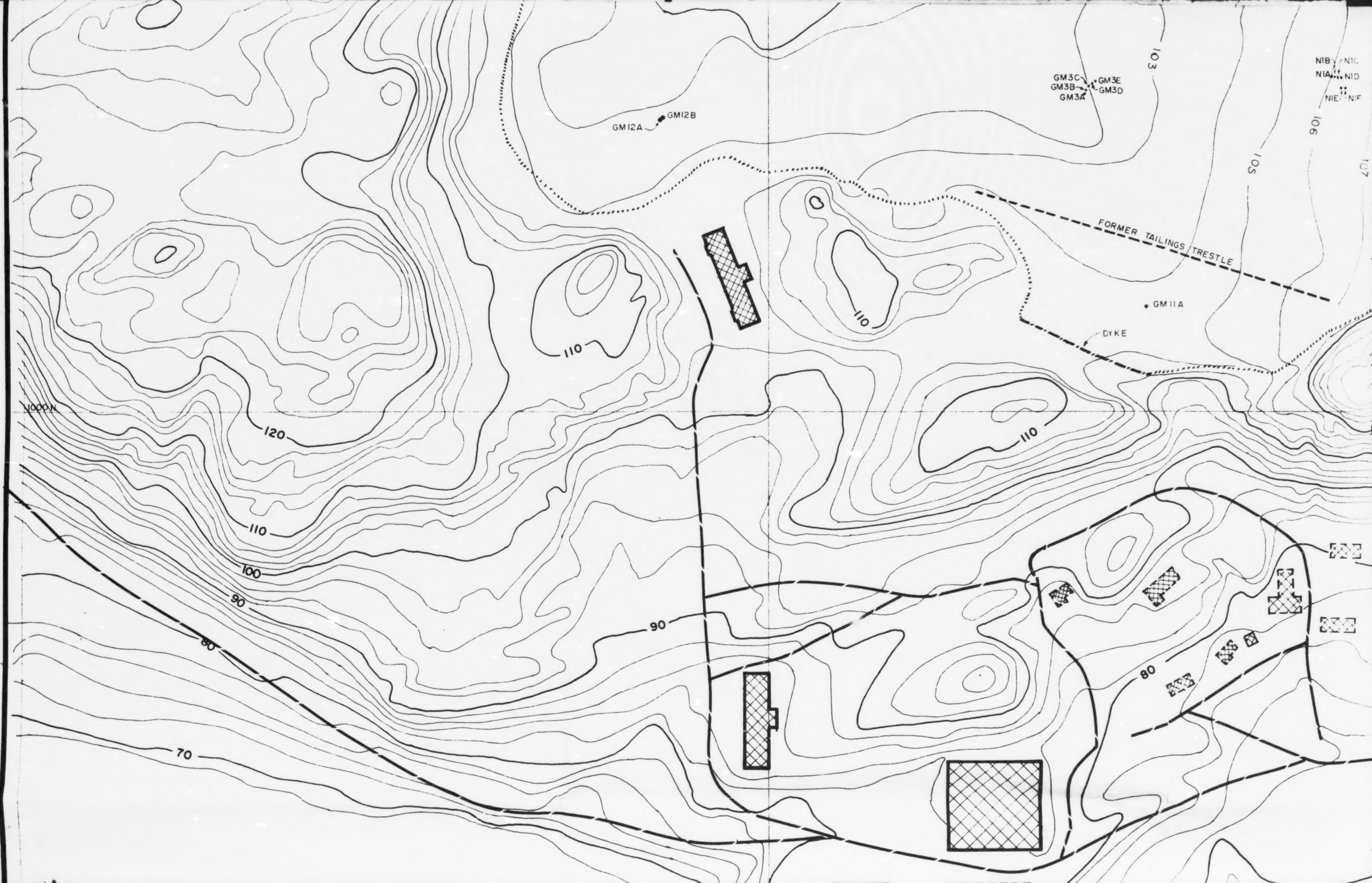

4000E
4500E
N3C
N3D
N3E
N3A
N3F
N3B
N3G
106
110
GM17A
GM17C
GM17B
100
100
GM25
GM9B
GM9A
GM9C
GM23
GM24
N6D
N6B
N6E
N6A
N6C
GM4A
GM4B
GM4C
GM8A
DYKE
GM20
GM6C
GM6B
GM6A
GM1
GM5A
100
GM2C
GM2A

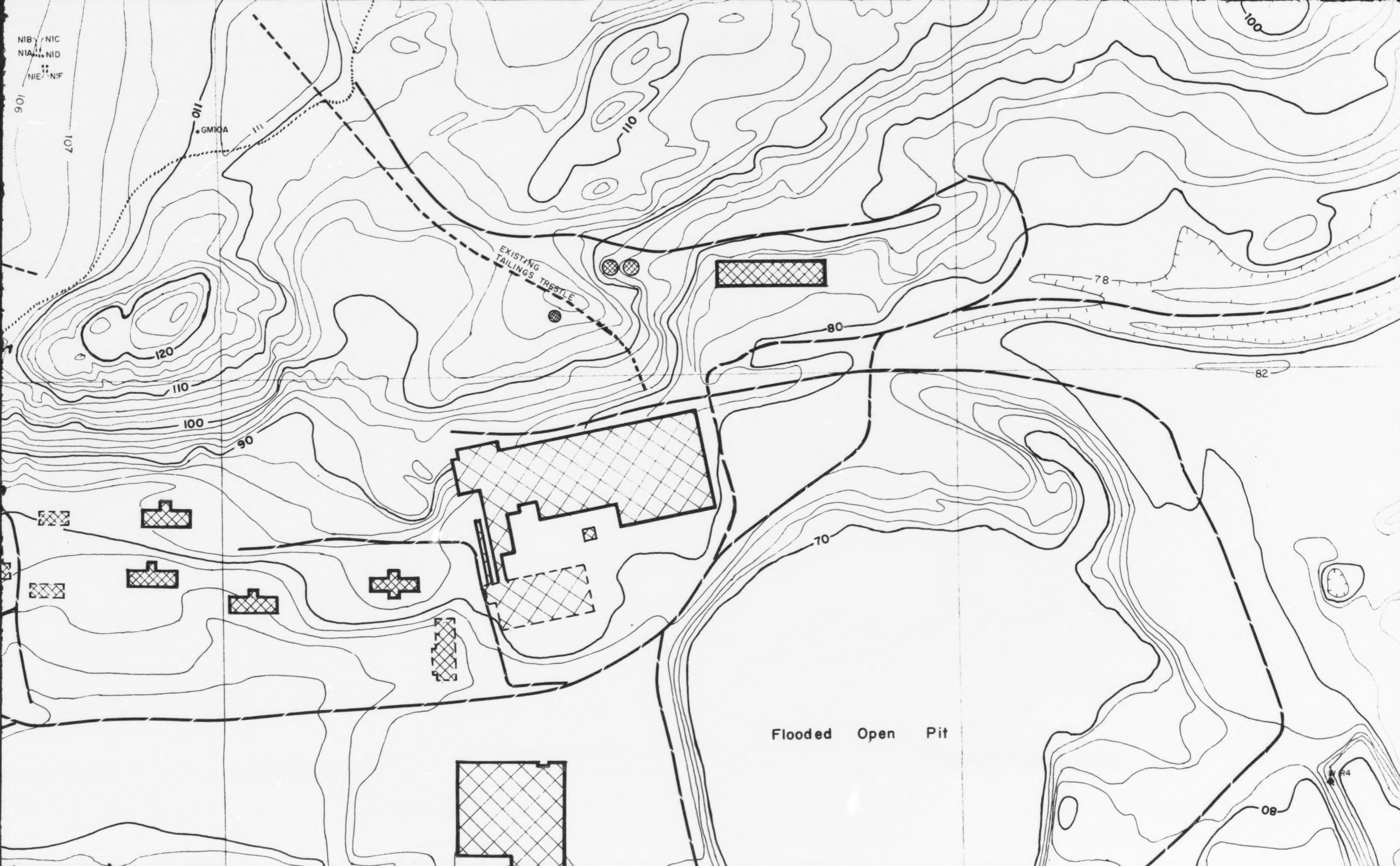

4500E
5000E
106
110
98
100
100
100
100
98
GM9B
GM9A
GM9C
GM 23
GM 24
DYKE
GM1
1500 N
90
100

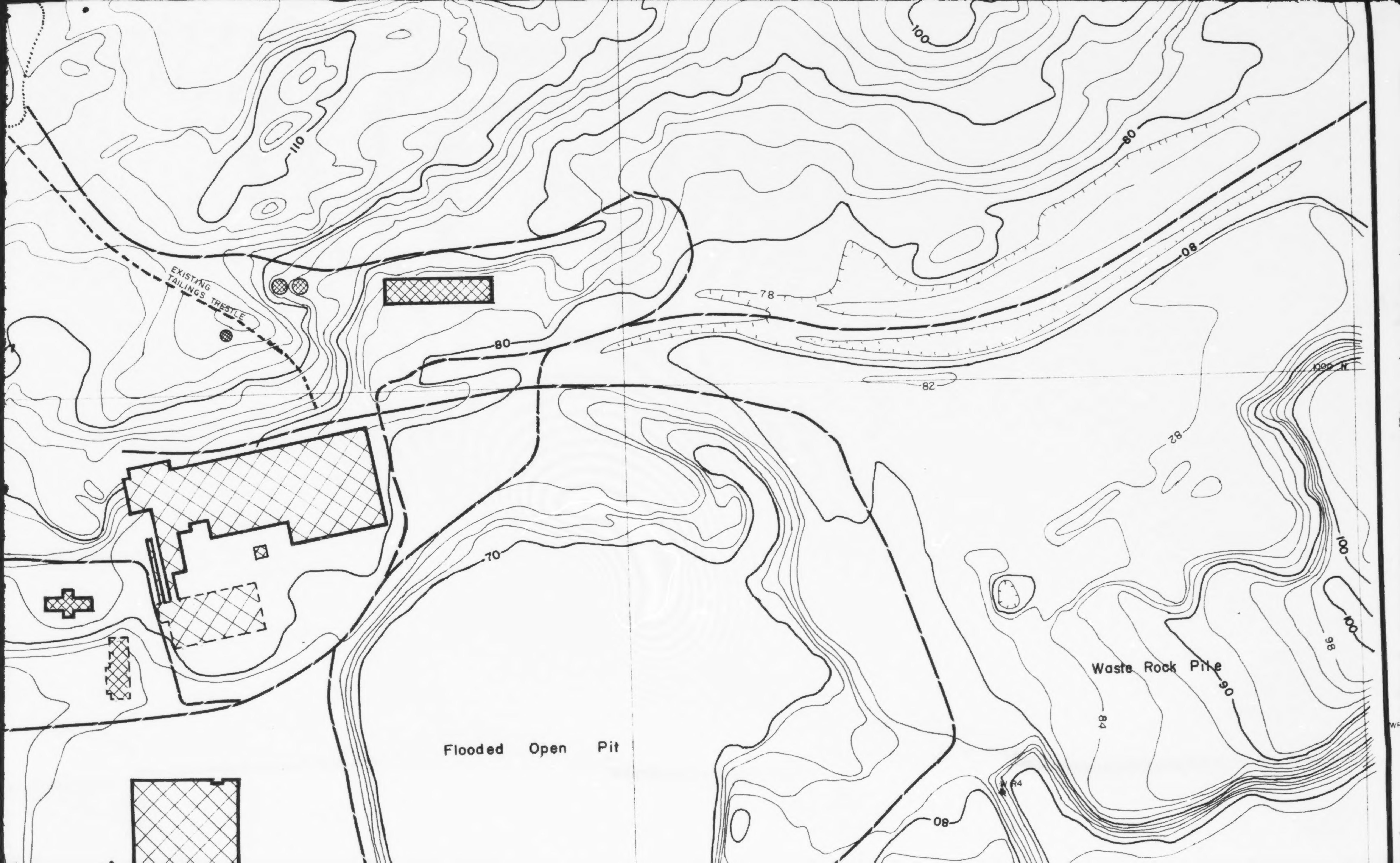

GM19A
GM19B
GM19C
100
GM6C
GM6B
GM6A
GM20
1500 N
GM5A
120
GM13A
GM13B
GM 18A
GM2
130
102
METEOROLO
TOWER SITE
GM7A
130
N2E
N2F
N2G
N2H
N2I
N2D
N2C
N2A
N2B
Gunnar Ma
Tailing
APPROX. EDGE OF TAILINGS
101
104
103
GM3C
GM3B
GM3A
GM3E
GM3D
N1B
N1C
N1A
N1D
N1E
N1F
GM12A
GM12B
106
105
107
FORMER TAILINGS TRESTLE
110
110
GM11A
DYKE
1000 N
120
110

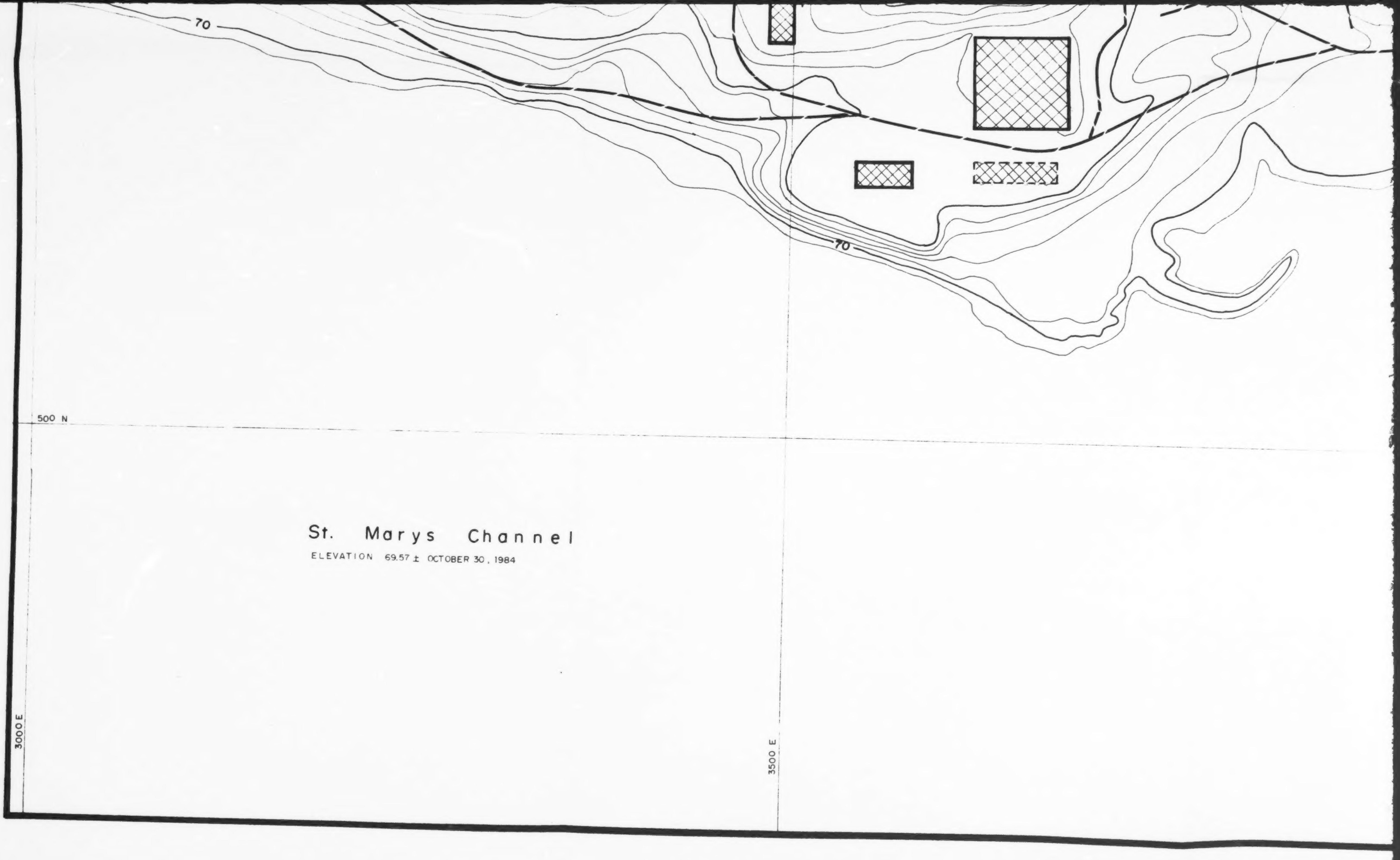

GM8A
DYKE
GM20
GM6C
GM6B
GM6A
GM1
GM5A
100
GM2C
GM2A
GM2B
102
METEOROLOGICAL TOWER SITE
Gunnar Main Tailings
106
109
104
GM22
103
N1B
N1C
N1A
N1D
N1E
N1F
106
107
105
110
GM10A
111
110
TAILINGS TRESTLE
GM 11A
EXISTING TAILINGS TRESTLE
78

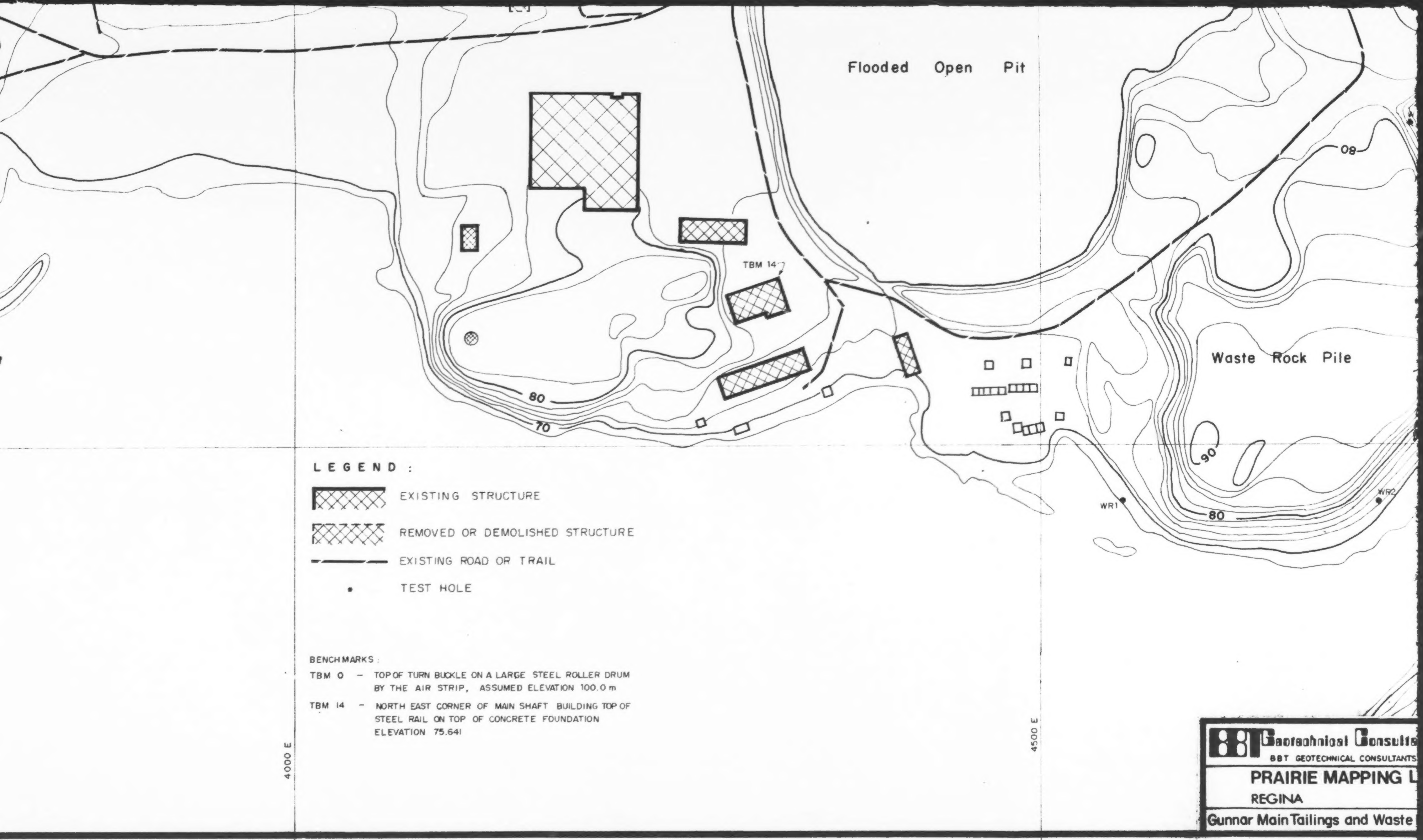

DYKE
GM1
GM22
90
1500 N
100
106
110
100
80
08
78
EXISTING
TAILINGS TRESTL


GM12A
GM12B
GM3C
GM3E
GM3B
GM3D
GM3A
N1B
N1C
N1A
N1D
N1E
N1F
103
105
106
107
FORMER TAILINGS TRESTLE
GM11A
DYKE
110
110
110
110
120
110
100
90
90
80
80
70
1000 ft.


N1B
N1C
N1A
N1D
N1E
N1F
106
107
110
GM10A
111
110
100
EXISTING TAILINGS TRESTLE
120
110
100
90
78
80
82
70
Flooded Open Pit
R4
80


100
110
80
80
EXISTING TAILINGS TRESTLE
78
80
1000 N
82
82
70
100
100
98
Waste Rock Pile
90
84
Flooded Open Pit
WR4
80
WR


70
70
500 N
3000 E
3500 E
St. Marys Channel
ELEVATION 69.57 ± OCTOBER 30, 1984


Flooded Open Pit
Waste Rock Pile
TBM 14
80
70
80
90
80
WR1
WR2
4000 E
4500 E

LEGEND:

- ▨ EXISTING STRUCTURE
- ▨ REMOVED OR DEMOLISHED STRUCTURE
- ▬ ▬ EXISTING ROAD OR TRAIL
- • TEST HOLE

BENCHMARKS:

TBM 0 – TOP OF TURN BUCKLE ON A LARGE STEEL ROLLER DRUM BY THE AIR STRIP, ASSUMED ELEVATION 100.0 m

TBM 14 – NORTH EAST CORNER OF MAIN SHAFT BUILDING TOP OF STEEL RAIL ON TOP OF CONCRETE FOUNDATION ELEVATION 75.641

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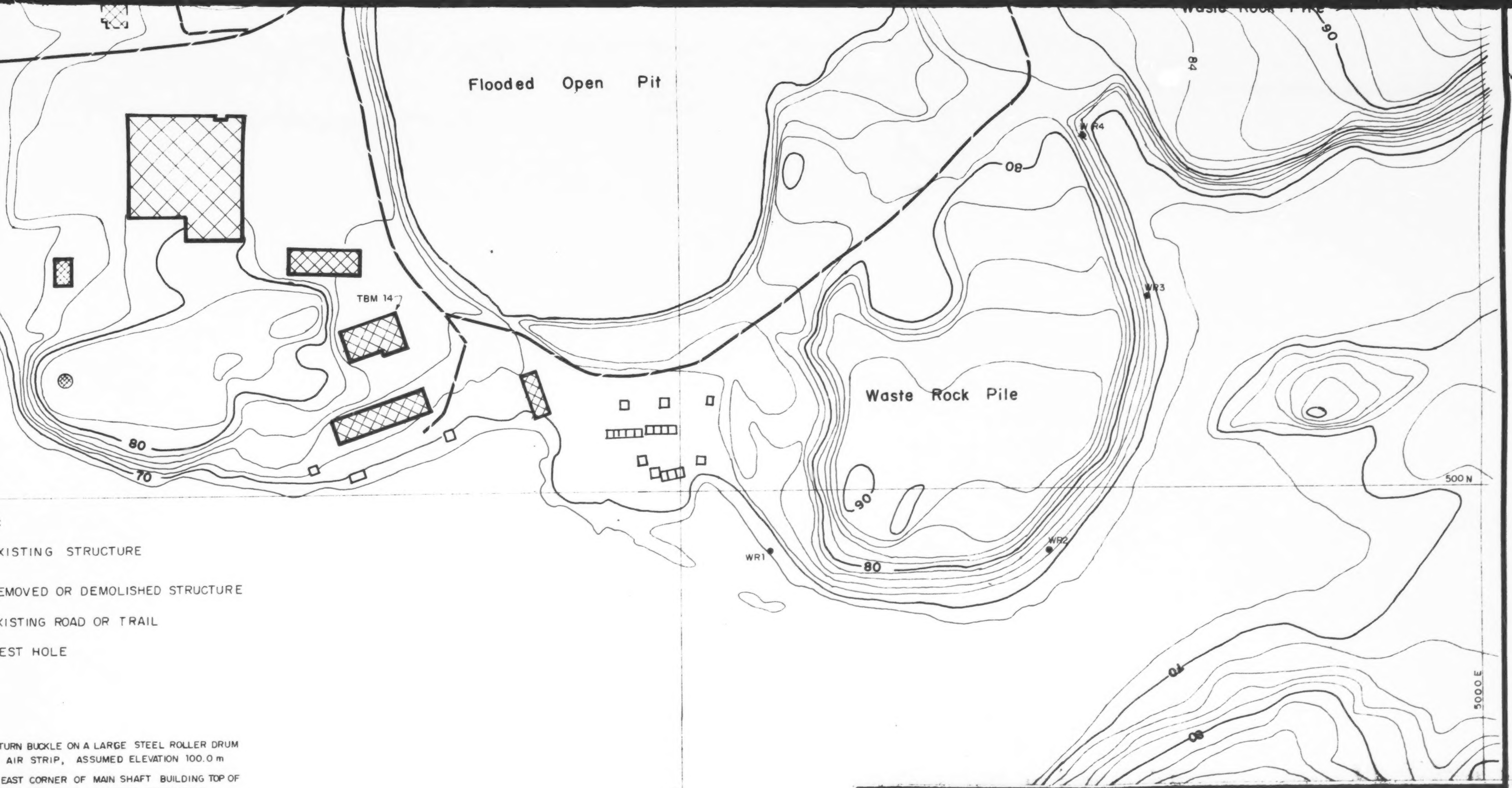
REGINA

Gunnar Main Tailings and Waste


Waste Rock Pile
90
84
WR5
Flooded Open Pit
WR4
80
TBM 14
WR3
Waste Rock Pile
80
70
500 N
90
WR2
WR1
80
70
80
5000 E
4500 E
XISTING STRUCTURE
EMOVED OR DEMOLISHED STRUCTURE
XISTING ROAD OR TRAIL
EST HOLE
TURN BUCKLE ON A LARGE STEEL ROLLER DRUM
AIR STRIP, ASSUMED ELEVATION 100.0 m
EAST CORNER OF MAIN SHAFT BUILDING TOP OF
RAIL ON TOP OF CONCRETE FOUNDATION
TION 75.641

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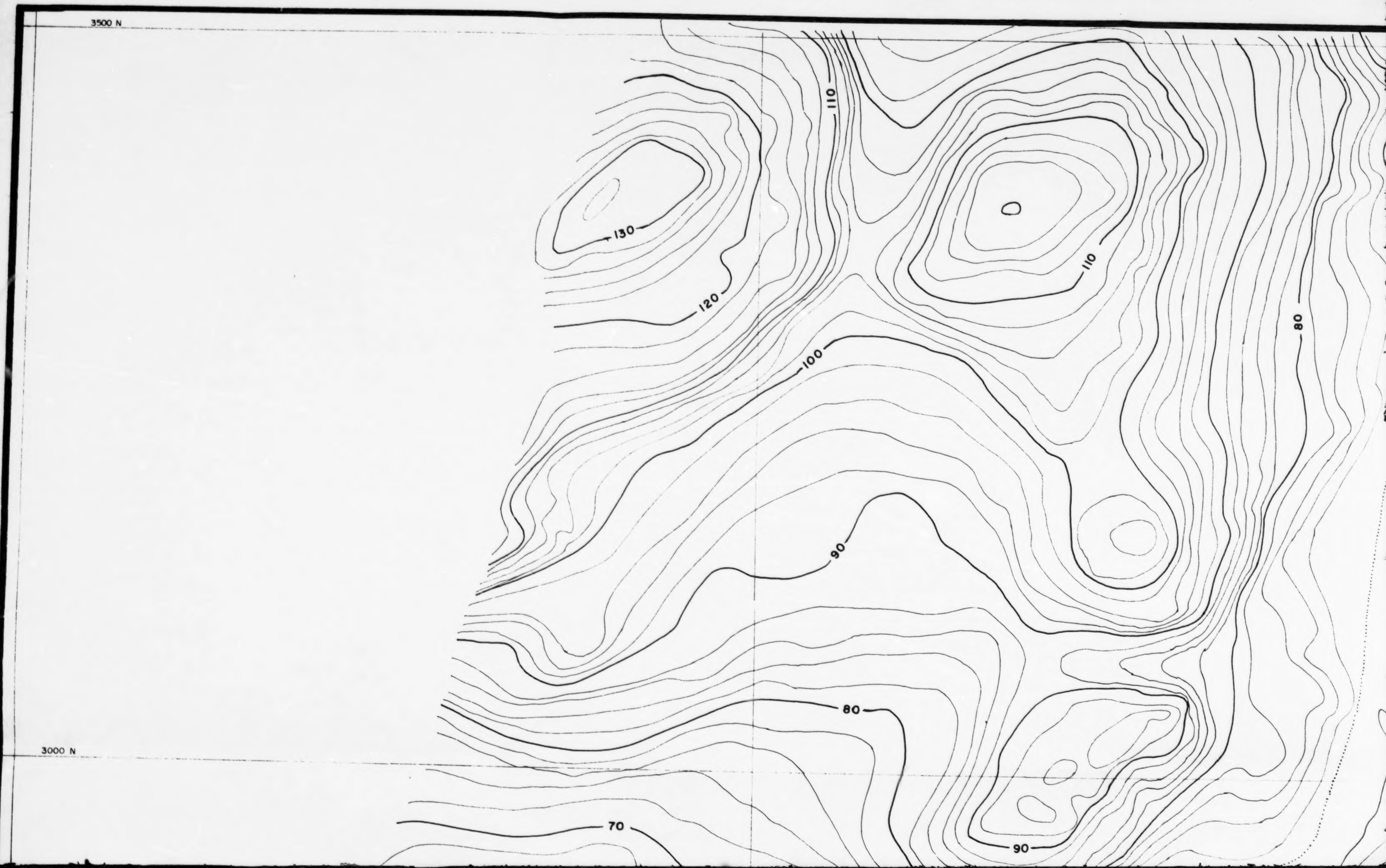
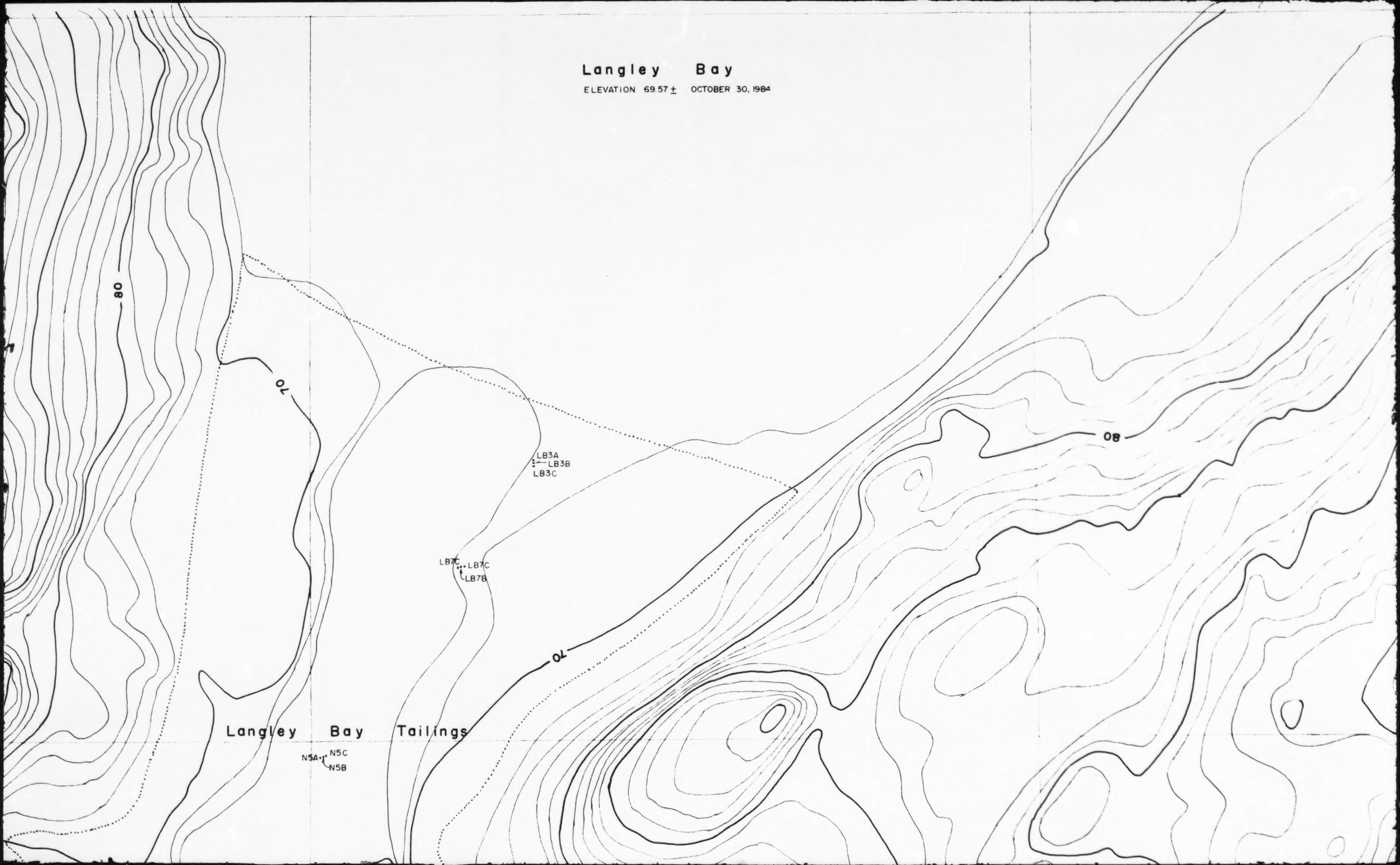
Gunnar Main Tailings and Waste Rock Pile

NATIONAL URANIUM TAILINGS PROGRAM
GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1 : 2000	DRAWN BY: W.T.	FIGURE 4.6
DATE JAN. 1986	APPROVED BY.	

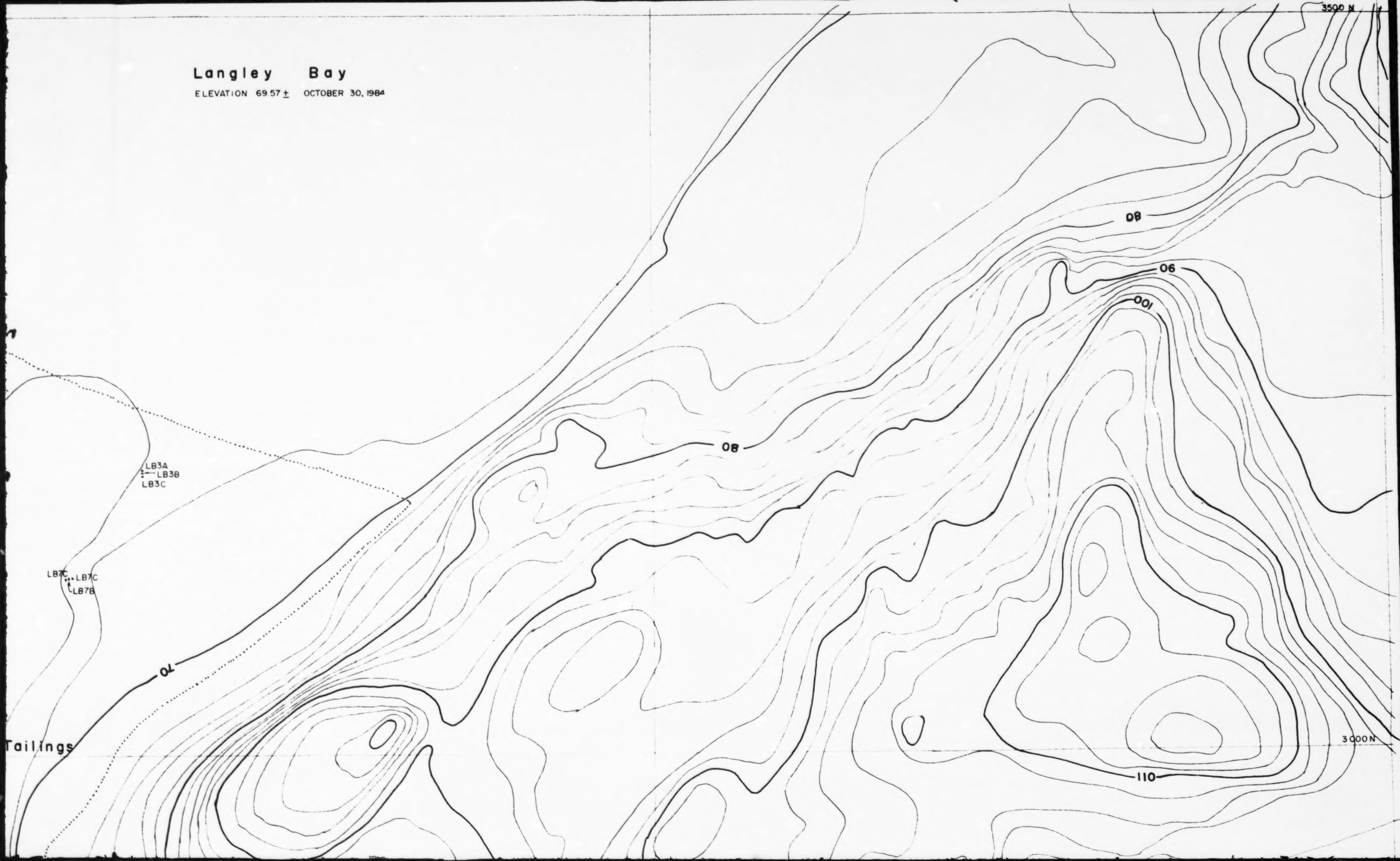

3500 N
130
120
110
110
100
90
80
80
3000 N
70
90



Langley Bay

ELEVATION 69.57 ± OCTOBER 30, 1984

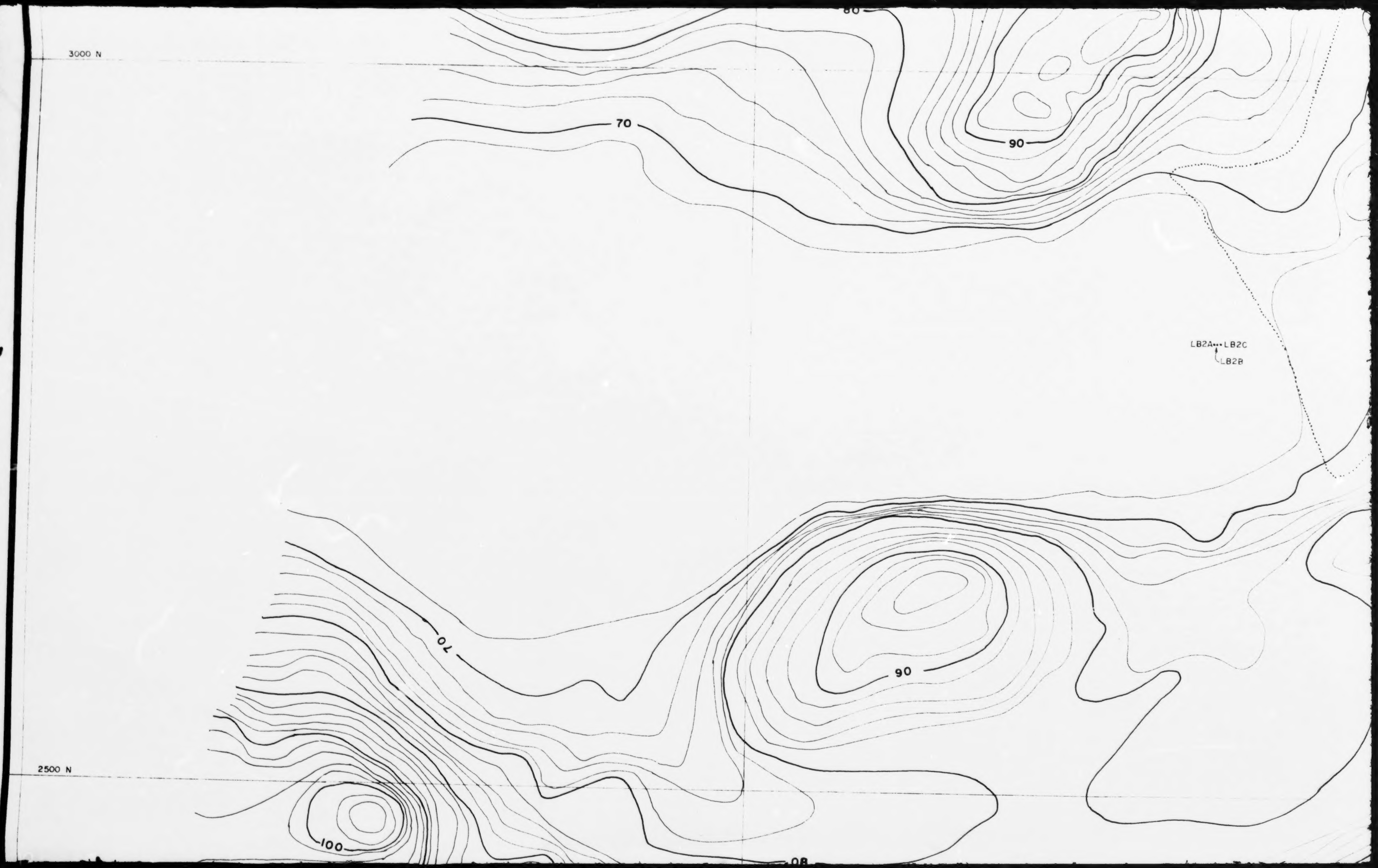
80
70
LB3A
LB3B
LB3C
LB7C
LB7C
LB7B
70
80
Langley Bay Tailings
N5A
N5C
N5B

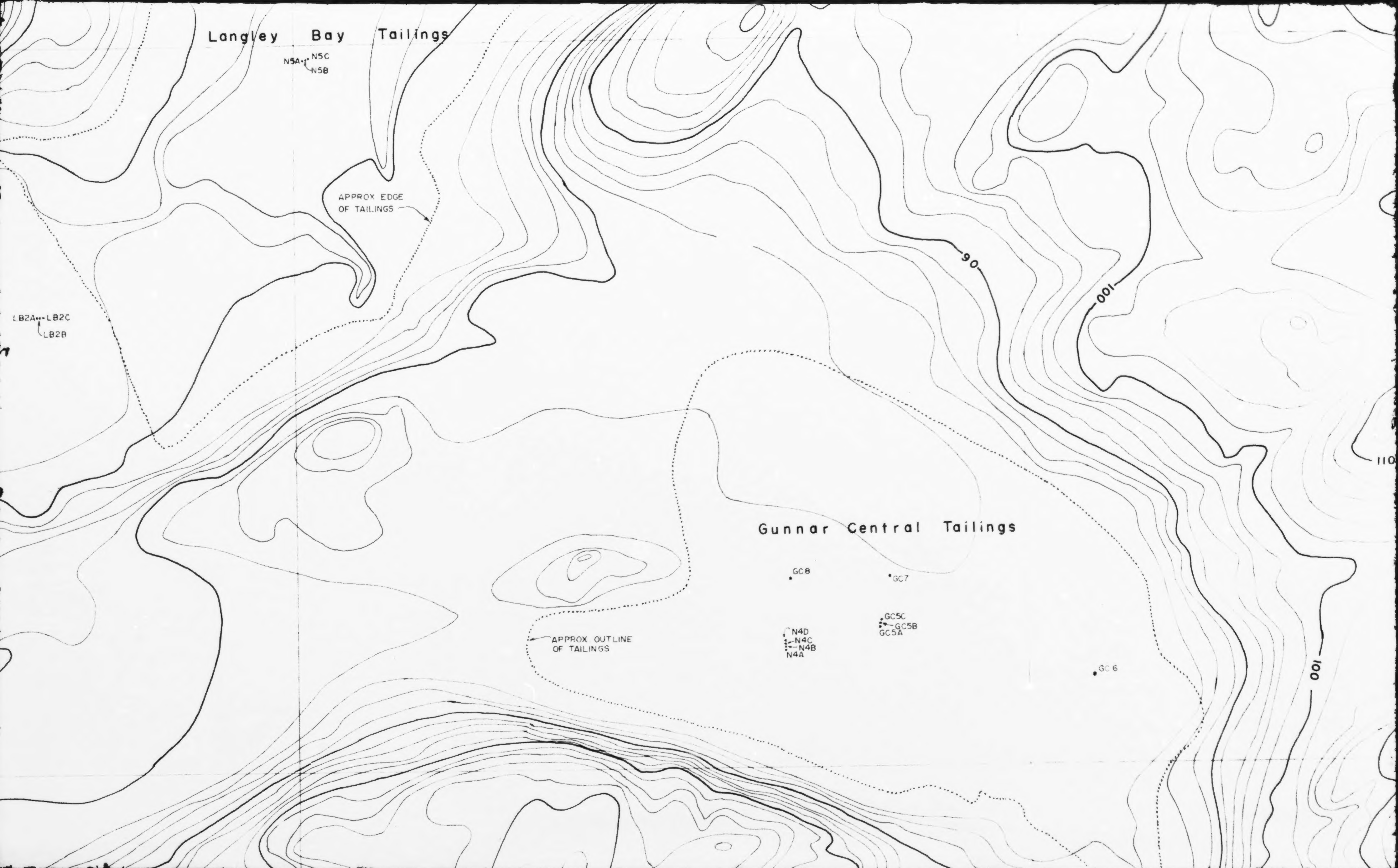


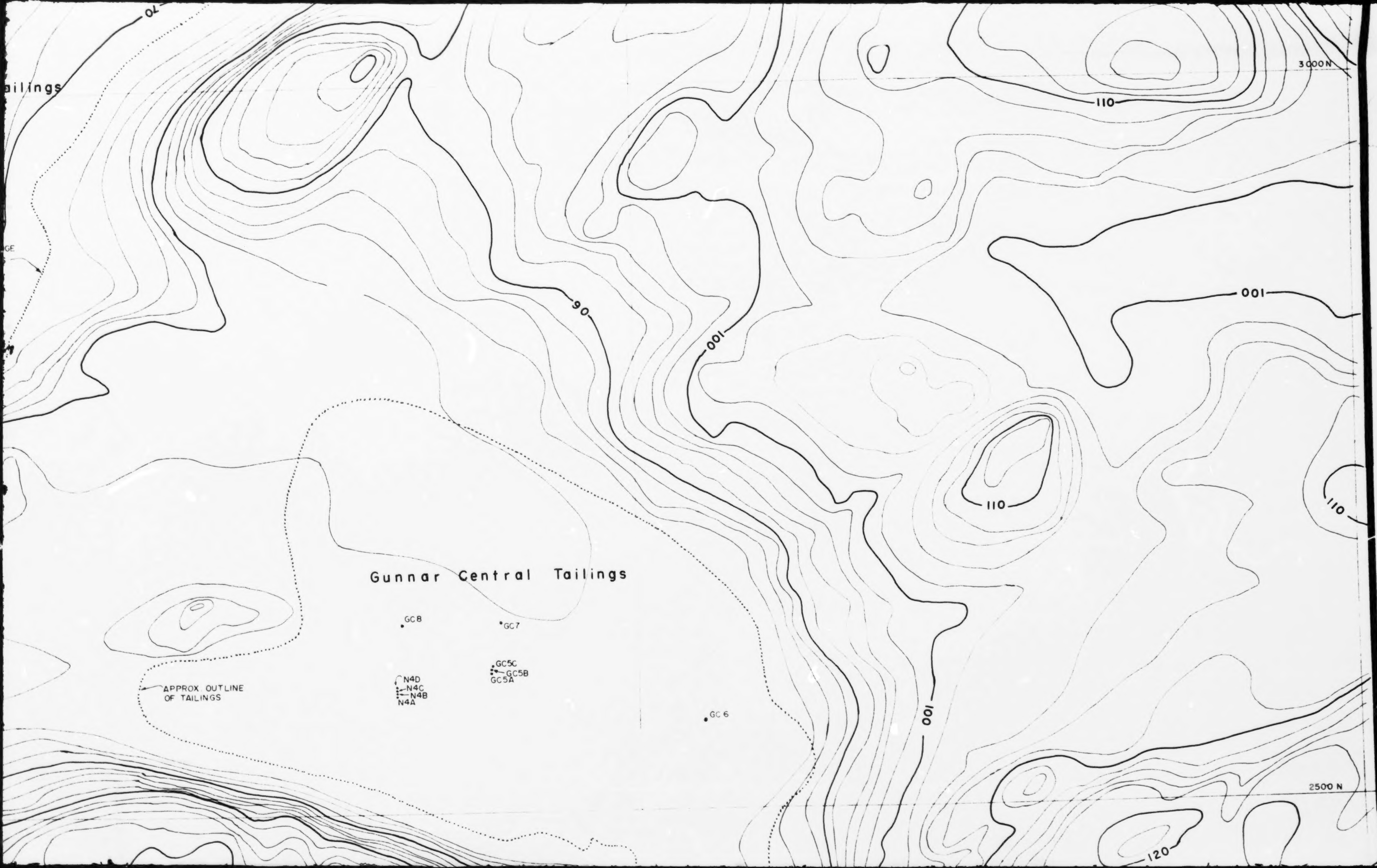
Langley Bay

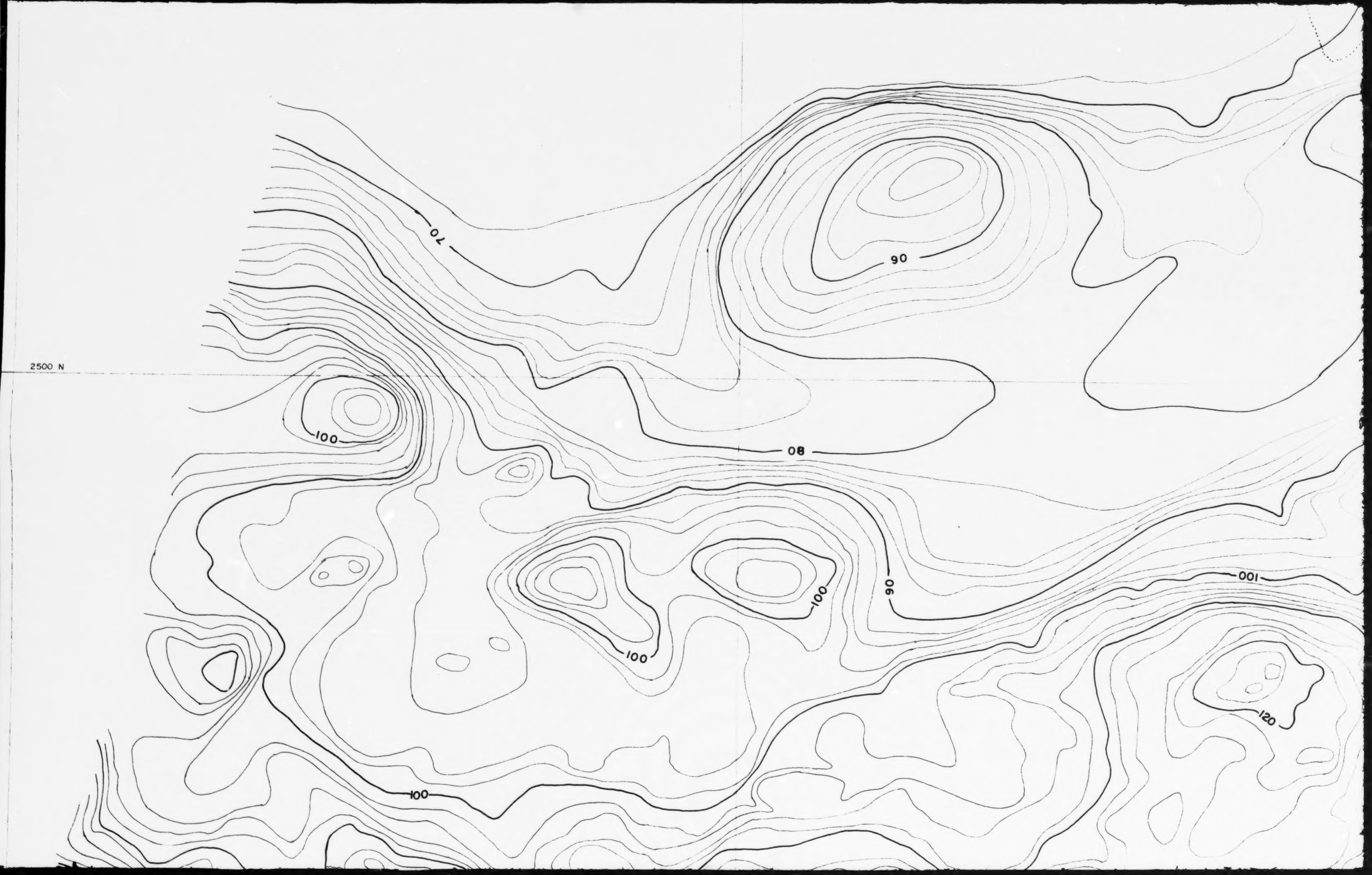
ELEVATION 69.57 ± OCTOBER 30, 1984

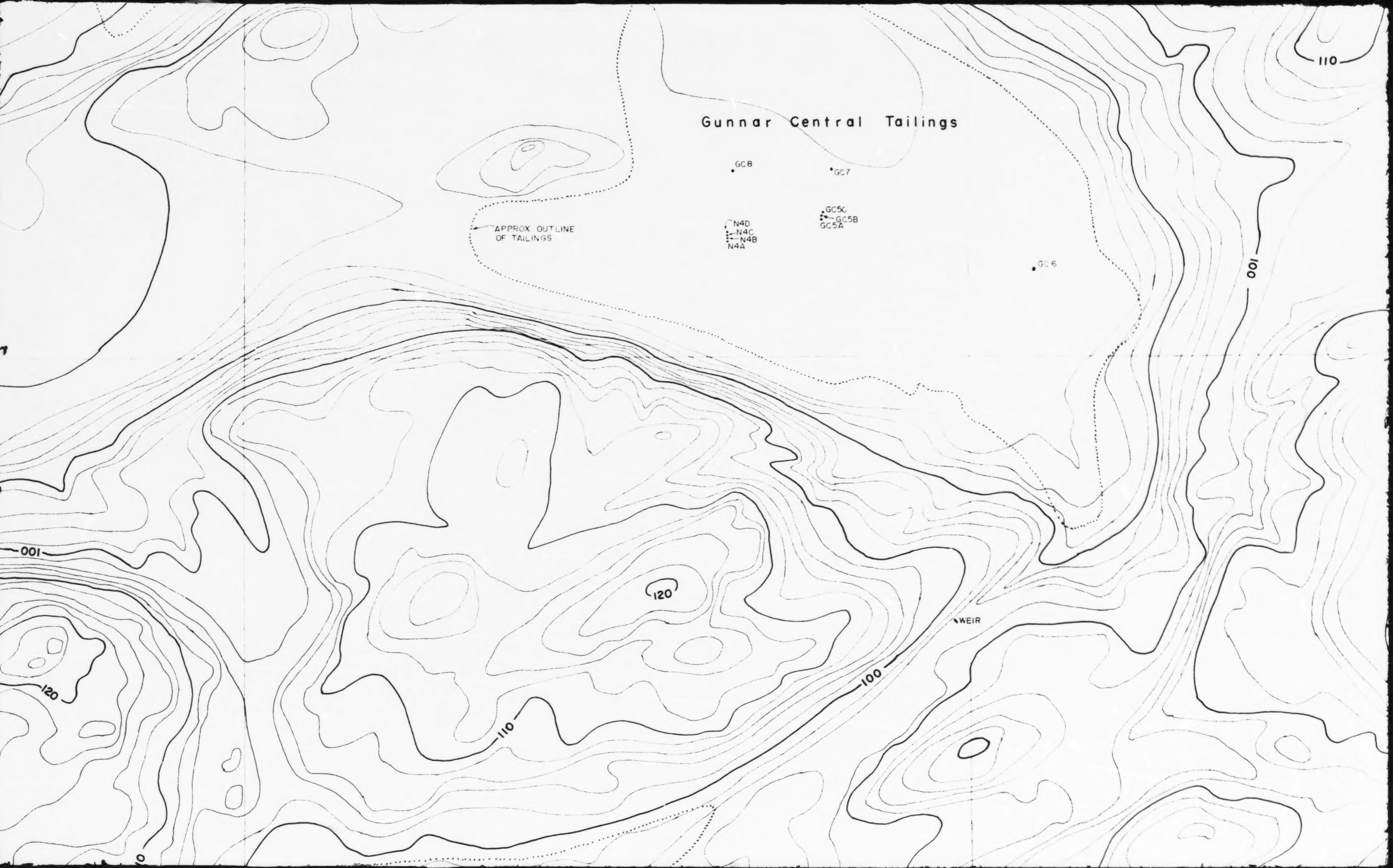
3500 N
80
90
100
80
LB3A
LB3B
LB3C
LB7C
LB7C
LB7B
70
Tailings
3000N
110

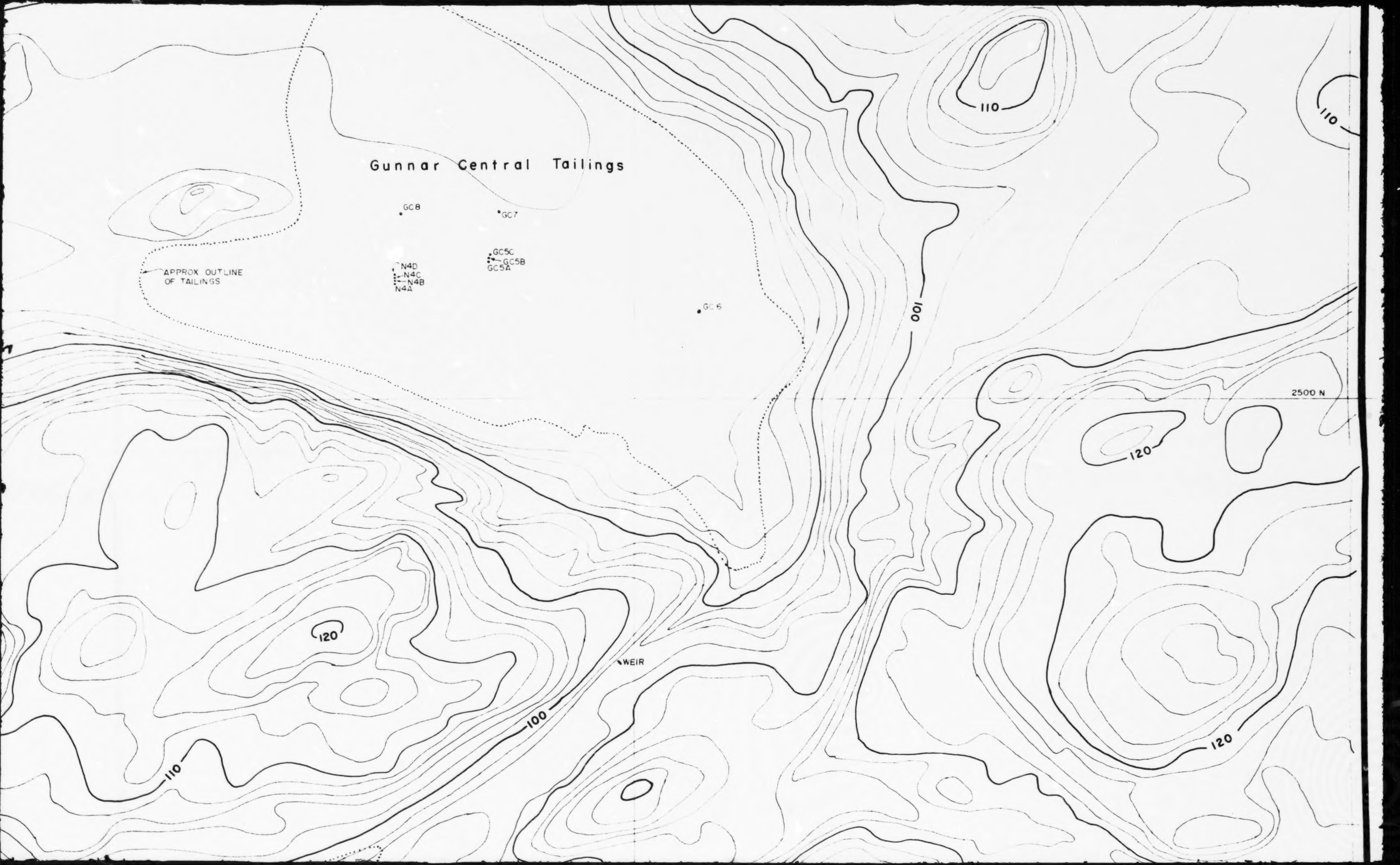

3000 N
80
70
90
LB2A
LB2C
LB2B
70
90
2500 N
100
80

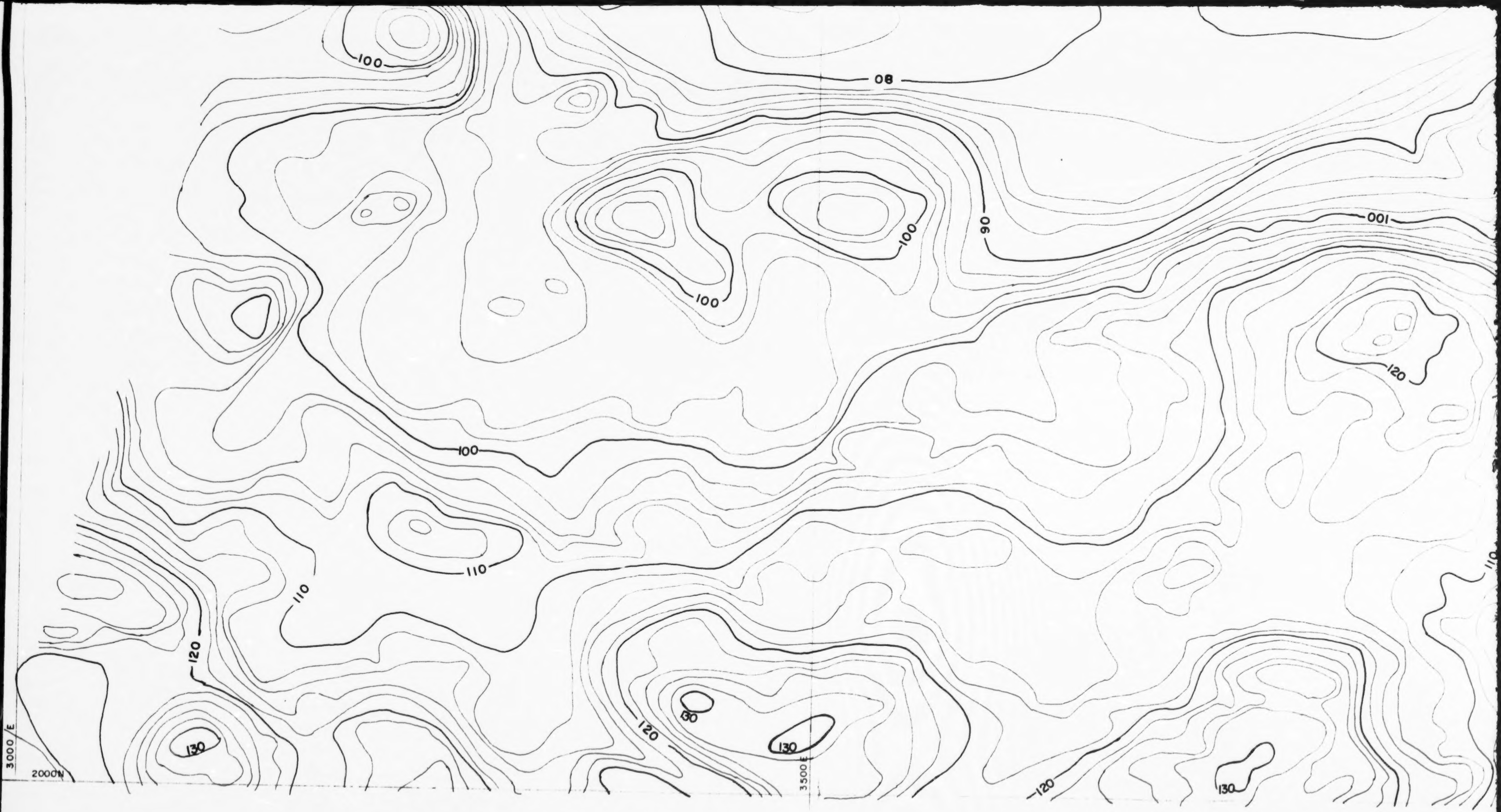

Langley Bay Tailings
N5A
N5C
N5B
APPROX EDGE OF TAILINGS
LB2A
LB2C
LB2B
90
100
110
Gunnar Central Tailings
GC8
GC7
GC5C
GC5B
GC5A
N4D
N4C
N4B
N4A
APPROX OUTLINE OF TAILINGS
GC 6
100

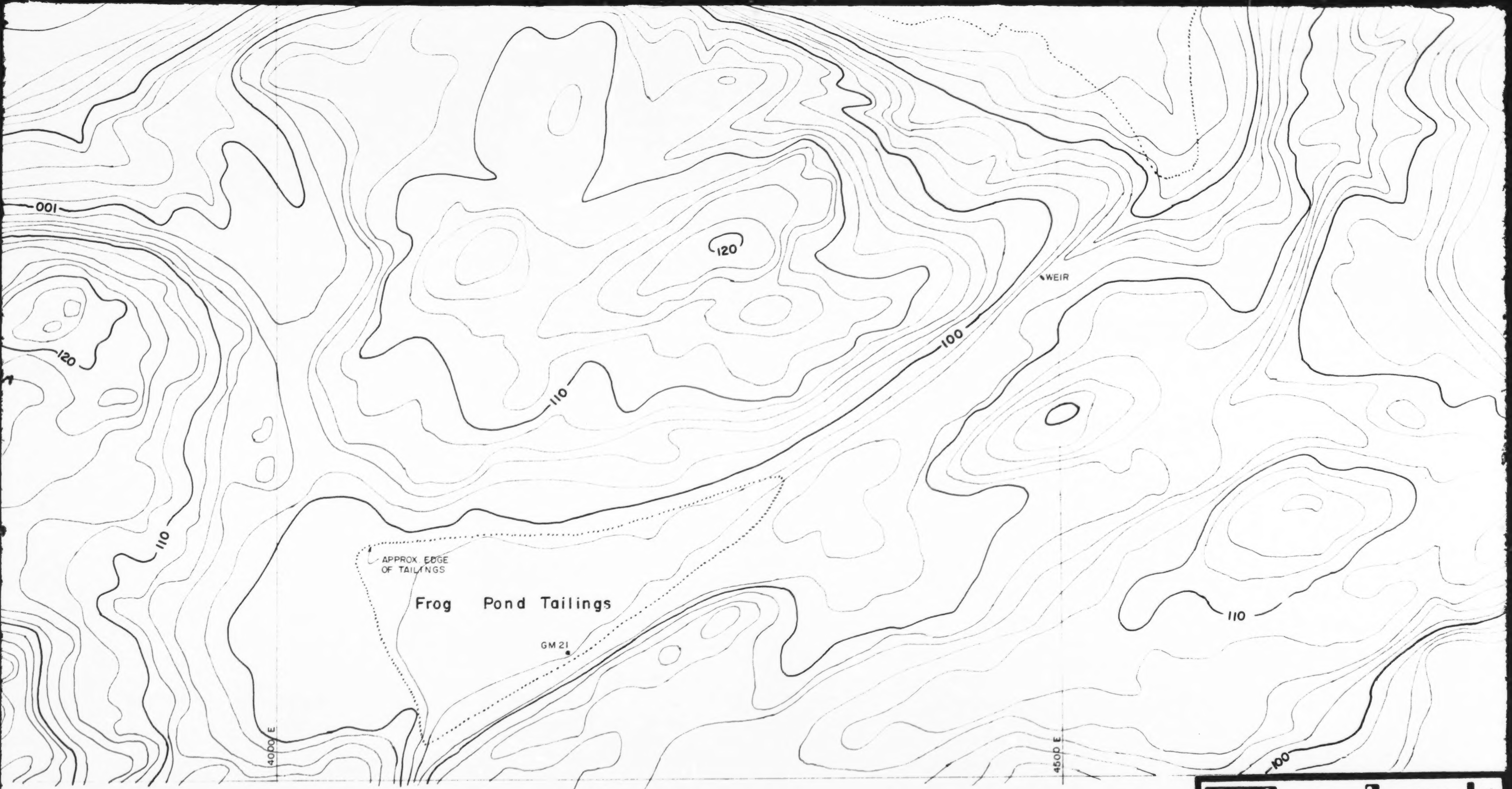

ailings
GE
70
90
100
100
100
110
110
110
120
3000N
2500 N
Gunnar Central Tailings
GC8
GC7
GC5C
GC5B
GC5A
N4D
N4C
N4B
N4A
GC 6
APPROX OUTLINE
OF TAILINGS


2500 N
70
90
100
80
100
90
100
100
100
120
100


Gunnar Central Tailings
GC8
GC7
GC5C
GC5B
GC5A
N4D
N4C
N4B
N4A
GC6
APPROX OUTLINE
OF TAILINGS
WEIR
110
100
100
100
120
120
110
100


Gunnar Central Tailings
GC8
GC7
GC5C
GC5B
GC5A
N4D
N4C
N4B
N4A
APPROX OUTLINE OF TAILINGS
GC6
110
110
100
2500 N
120
120
120
WEIR
100
110
120


100
80
90
100
100
100
120
100
110
110
120
130
120
130
130
120
130
110
3000 E
2000N
3500 E


001
120
120
WEIR
100
110
110
APPROX EDGE OF TAILINGS
Frog Pond Tailings
GM 21
110
4000 E
4500 E
100

BENCHMARK ·
TBM 0 – TOP OF TURN BUCKLE ON A LARGE STEEL ROLLER DRUM
BY THE AIR STRIP, ASSUMED ELEVATION 100.0 m

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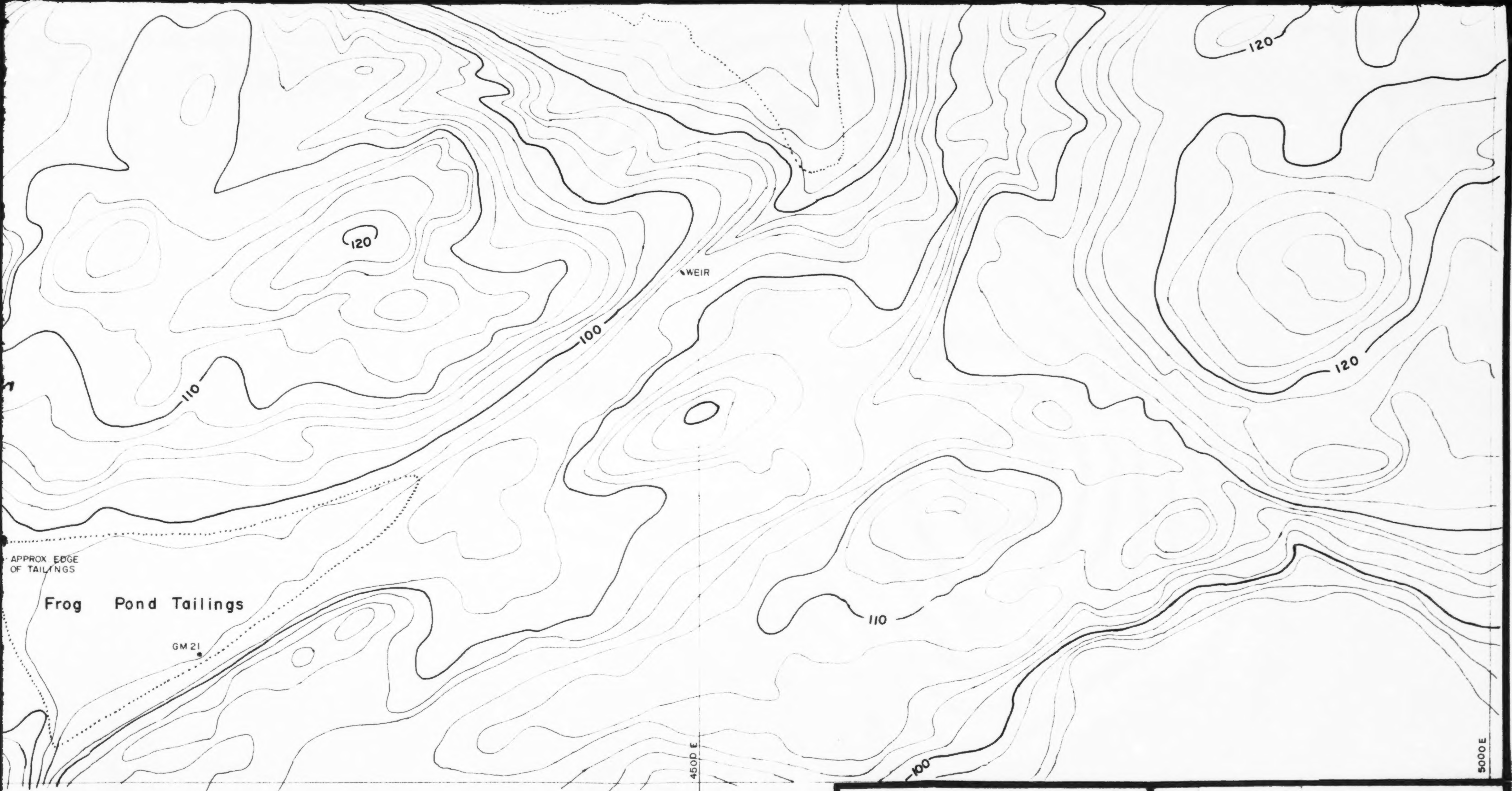
Gunnar Central & Langley Bay Tailings


120
120
120
120
WEIR
100
110
110
100
APPROX. EDGE OF TAILINGS
Frog Pond Tailings
GM 21
4500 E
5000E

BENCHMARK:
TBM 0 – TOP OF TURN BUCKLE ON A LARGE STEEL ROLLER DRUM
BY THE AIR STRIP, ASSUMED ELEVATION 100.0 m

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GUNNAR FIELD STUDY
SOUTH OF URANIUM CITY, SASKATCHEWAN

SCALE 1:2000	DRAWN BY: W.T.	FIGURE 4.7
DATE: JAN 1986	APPROVED BY:	